Materials & Methods

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FEATURE ARTICLES

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SEMI-ANNUAL INDEX

DEPARTMENTS

NEXT MONTH: What Industry Needs in Engineering Materials .. Machining of Heated Metals ... Selecting Nonferrous Alloys ... Salt Bath Brazing ... Ford Welded Sheet Process ... New High Temperature Silicone Material ... Selectively Hardening Gear Teeth in Salt Bath ... New Blackening Bath

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The Materials Outlook

As we are about to wind-up a hectic 1950, the situation in regard to the supply and prices of materials is more confused and erratic than ever. Whether or not there are enough materials to go around is still being debated, but the fact remains that many consumers of restricted metals have plenty of worries. Warehouse supplies of certain steels, for example, are depleted, with no indications that stocks will be replenished.

In the face of constantly rising prices, steel scrap has sold at less than the established market, with few takers.

Constant fluctuation between war with the Chinese Reds and the end of fighting in Korea has made all markets jittery. Possibly the safest policy for materials buyers is one which maintains only the lowest safe supply, with stock being filled when and if lower prices prevail. There is one major flaw in this policy, and that is that a low price today does not assure an equally low price on the day of shipment.

Even the weather is working against the supply situation, with heavy snow storms halting major producers in Pittsburgh and Cleveland, plus some disruption in the Chicago-Gary area.

Industry groups are becoming irritated at the snail-like pace of government bureaus in reactivating defense metal producing plants. Typical is the Magnesium Association, which has urged action in reopening several magnesium plants which could eliminate the shortage in that material.

Recent action in putting into service some stand-by aluminum plants will help in this critical metal late in 1951. Most of the aluminum to come from the first plants back in action will go into government stockpiles. Alcoa will reopen plants which could not be operated profitably during normal periods because of a scarcity of low-cost electricity.

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The Materials Outlook *(Continued)*

Certain areas of this country are likely to feel the pinch of a power shortage such as that recently encountered in Canada. Early this year Ontario was reported to have ample power, but as industry engaged in defense production for Canadian, British and United States needs, steps had to be taken to save electricity. As a result Hamilton and Toronto, among a few other cities, extended daylight saving time through November.

One of the first groups to emerge as casualties of tightening supply situation is the plastic injection molding group. Reliable estimates indicate that as many as 300 molders face financial ruin due to the shortage of polystyrene molding powder. The use of polystyrene was expanding rapidly when the synthetic rubber program took a large portion of the available styrene production of this country. During the past summer polystyrene powder represented almost one-third of all plastic molding powders produced in this country. Since allocations of the material are based on 1949 use, many companies will have to do without the fastest growing plastic material, which has been going into a wide variety of products.

Now that the National Production Authority has had a chance to talk to leaders of various industry groups, an ever increasing list of materials is going under controls. The list now--or soon will--include aluminum, zinc, columbium, cobalt and copper. Steel is expected to go under complete control soon to help relieve the chaotic condition which now prevails.

Labor, more than management, is kicking about the controls. They feel most strongly about the aluminum and proposed copper orders, claiming that the shutting off of materials will cause many workmen to lose jobs before defense work becomes available. CIO suggests a more realistic approach to allocations could be worked out to save those industries where substitutions are least possible.

Steel which has been allocated for steel plant production will have the effect of tightening the supply temporarily, until these plants actually can produce.

The NPA order cutting the use of cobalt by 70% will hit the television, radio and other industries using Alnico permanent magnets. Likewise affected will be the new corrosion resistant alloys such as Elgiloy, which have high nickel content. The order might be eased somewhat late in December if military needs appear to be met.

Soon (possibly before this is published) the Munitions Board is expected to furnish the NPA tentative figures on military and stockpile materials requirements for at least the first half of 1951. When this is made known there will be an opportunity of estimating, with reasonable accuracy, how much will remain for civilian uses. Naturally, the figures will be secret, but they will provide a basis on which to plan.

News Digest

Cold Increases Metal Hardness

New evidence that hardening of steel takes place more completely at extremely low temperatures is being uncovered at Mass. Institute of Technology, according to its president, Dr. James R. Killian, Jr.

In some types of steel the amount of hardening, as measured by the amount of hard martensite formed, has been found to increase from very little at room temperature to nearly 100% at the temperature of liquid helium (−453 F). In other steels, hardening does not begin until temperature is dropped below −240 F. Cold working is still more effective at these extremely low temperatures.

According to Killian, these principles are already being applied in the manufacture of stainless steel where rolling operations designed to harden the metal are being carried out at temperatures below freezing. Even more important is the contribution of this research to the theory on the mechanism of steel hardening.

Martempering Patent Sought

Two bills have been recently introduced in Congress to assist Richard F. Harvey in obtaining a patent on Martempering. This relatively new heat treatment, also known as "step quenching," is said to have been developed by Harvey 12 years ago. Patent application No. 320,998 was filed in 1940.

Martempering involves interrupting the quench at about 400 F, allowing the work to reach this temperature throughout, then cooling in air to room temperature. This procedure minimizes distortion and quench cracking.

ASM Papers Record Progress in Materials, Processes

More than 40 technical papers on metals were presented by the American Society for Metals at the recent National Metal Congress in Chicago. The principal conclusions of those papers believed to be of most interest to our readers have been briefly summarized below.

Carbonitriding

The rapidly developing heat treatment known as carbonitriding was the subject of two papers by G. W. P. Rengstorff, Battelle Memorial Institute, and M. B. Bever and C. F. Floe, Massachusetts Institute of Technology. Their papers were "The Carbonitriding Process of Case Hardening Steel" and "Constitution of Carbonitrided Cases."

The investigators found that the temperature of carbonitriding is the most important single variable in determining the composition of the case and, together with the cooling rate, its structure and properties. The case produced at 1300 F has a thick compound layer at the surface and an inner layer which consists of a decomposition product of carbon-nitrogen austenite and retained austenite. At higher temperatures, thickness of the compound layer decreases. Cases produced at 1500 to 1550 F have highest hardness, thinnest compound layer and greatest case depth. Time and temperature of carbonitriding determine the depth of case produced. Case depth after carbonitriding at 1500 F is approximately equal to that resulting from cyaniding for the same treatment time.

Oil quenching gives full hardening of the inner layers of carbonitrided cases on fairly large sections of plain carbon steel. Thus, the hardenability of carbonitrided cases is greater than that of carburized cases. Hardness of the outer compound layer, although only moderate, is independent of the cooling rate.

Tempering 2 hr at 500 F raises hardness of the outer layer in steel carbonitrided at 1300 F, but has no such effect on specimens treated at higher temperatures. The inner layer is softened progressively with higher tempering temperatures and longer times. At tempering temperatures of 700 F or above, specimens carbonitrided at 1500 and 1550 F retain their hardness somewhat better than comparable carburized specimens.

The authors also found that similar case structures are produced with widely varying gas composition, and appreciable amounts of water vapor in the inlet gas were not detrimental. Core structures of carbonitrided specimens are affected by heating temperature and cooling rate.

Embrittlement by Steam

Most commercial heat treating atmospheres contain water vapor both as normal humidity and as a product of combustion. The effects of this water vapor, a source of hydrogen, were reported by C. A. Zapffe, research metallurgist, and R. L. Phebus, Univ. of Pennsylvania, in "Embrittlement of Stainless Steel by Steam in Heat Treating Atmospheres."

The authors used a bar-bend test to measure embrittlement. They found that Types 403 and 410 bend a full 180 deg when quenched from air or dry helium over the entire hardening

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News Digest

range, but will fracture throughout the same range when the heat treatment is conducted in steam. For commercial treatments at about 1830 F the bend values may be as low as 20 deg.

Type 414 can be hardened from temperatures up to about 1830 F in dry helium without loss of 180-deg bendability, but this steel will fracture at 30 deg following an air treatment at the same temperature. Type 431 behaves similarly but equal embrittlement is produced only at higher temperatures.

Type 416, the free-machining modification of 410, is less ductile than 410 under normal conditions and is damaged proportionately more by steam. Type 440-C, which normally has low bendability in the hardened condition, shows bend values as low as 5 deg when heat treated in steam.

Hardenability Test

It is well known that some steels harden throughout larger sections than those to which the Jominy test is equivalent. For these cases, the standard Jominy test gives no information concerning the limiting hardenability of the steel and accurate predictions are not always possible. In "A Hardenability Test for Deep Hardening Steels," William Wilson, Jr., Armour Research Foundation, proposes a new test that would extend the usefulness of the Jominy principle.

The new test specimen is 1¼ in. dia by 11 in. long. It is machined from 1½-in. round stock allowing ⅛ in. of stock removal to eliminate any prior decarburization. Each specimen is provided with seven thermocouple wells; these are drilled radially through the center of the bar and to a depth of 1/16 in. from the opposite side of the bar. Water at room temperature is used to quench one end of the hardenability bar and is directed vertically from a ½-in. dia jet orifice with a velocity corresponding to a free jet height of 3½ in.

The quenching fixture is much more elaborate than that used for the Jominy test. An annular transite plate attached to the jet orifice supports a tubular furnace over the jet. The specimen is supported from the top of this furnace and is practically surrounded by the furnace during the test.

Test conditions have been adjusted to reproduce the average cooling curves observed in commercial oil quenching. The new test extends the field of hardenability testing to include all steels with an ideal diameter less than 21 in. By use of additional controlled heating element pairs in a taller furnace and by lengthening the test bar, this limit could be further extended.

Sigma Phase Formation

One of several papers on sigma phase presented at the ASM meeting was "Hardening of High Chromium Steels by Sigma Phase Formation" by John J. Gilman, Crucible Steel Co. of America.

Certain high-chromium steels have the important ability to harden at high temperatures (1200 to 1600 F) and to retain their hardness for an indefinite period of time at the hardening temperature. Because of this ability they are useful for applications involving high-temperature erosion or wear.

Gilman used hardness measurements and microscopy to study the rate at which sigma phase forms in several high-chromium austenitic-ferritic steels. He found that the rate of sigma formation is increased by presence of initial ferrite, increased temperature in the sigma formation range, cold working and low rolling temperatures. Annealing at increasing temperatures (1700 to 2100 F) and repeated recrystallizations decrease the rate. Also, sigma forms much less rapidly in cast materials than in wrought ones; formation rate apparently depends on the rate of cooling during solidification. Thus the entire prior history of a steel determines the rate at which sigma phase may form in it and is equally as important in this connection as composition of the steel.

Composition was found to affect the behavior of these steels in three ways: (1) rate of sigma formation at a given temperature, (2) upper limit of the sigma formation range, and (3) the temperature below which the sigma forms at a negligible rate.

New Nickel Alloys

"Nickel-Aluminum-Molybdenum Alloys for Service at Elevated Temperatures" was the subject of a paper given by H. V. Kinsey, Dept. of Mines and Technical Surveys, and M. T. Stewart, National Research Council, both of Canada.

Results of their investigations indicate that alloys consisting of nickel, aluminum and molybdenum possess mechanical properties at 1500 F that are at least the equivalent of the best cobalt-base casting alloys. Since the metals used are not highly strategic and there appear to be no complications in melting and casting, these alloys show some promise for high temperature applications.

On the basis of data in their paper, the authors suggest two tentative specifications as follows:

1. Minimum properties at 1500 F —80,000 psi ultimate tensile strength, 2% tensile elongation, 150 hr rupture life at 35,000 psi, and 7% stress-rupture elongation. Composition—69.3-70.74 nickel, 7.76-8.36 aluminum, 21.0-22.0 molybdenum, 0.15 (max) silicon, 0.15 (max) iron and 0.10% (max) carbon. Nickel-aluminum ratio of 8.4:1 to 9:1.

2. Minimum properties at 1500 F —90,000 psi ultimate tensile strength, 2% tensile elongation, 200 hr rupture life at 35,000 psi, and 7% stress-rupture elongation. Composition—69.44-70.74 nickel, 7.76-8.27 aluminum, 21.0-22.0 molybdenum, 0.15 (max) silicon, 0.15 (max) iron, and 0.10% (max) carbon. Nickel-aluminum ratio of 8.5:1 to 9:1.

Zirconium-Iron Alloys

Zirconium-iron alloys are of interest both from the standpoint of improving the physical properties of zirconium metal and because iron is a nuisance element in zirconium metal production. A report on these alloys, "Constitution and Mechanical Properties of Zirconium-Iron Alloys," was presented by E. T. Hayes, A. H. Roberson and W. L. O'Brien, U. S. Bureau of Mines.

A heat treatable alloy which seemed to have a good combination of properties was one containing 3.3% iron. Hot-rolled, this alloy had 69,000 psi yield strength (0.1% offset), 94,000 psi tensile strength and 8% elongation. Quenched and drawn at 750 F, this alloy had properties of 104,000, 106,000 and 0.5%.

In a 2.5% iron alloy, cold working produced 100,000 psi yield strength, 122,000 psi tensile strength and 5.5% elongation. For a 4.6% alloy, these values were 94,000, 114,000 and 1.4%.

(Continued on page 108)

Plastics Men Teach, Learn at SPI Annual Conference

News Digest

A unique combination of technical and educational sessions featured the two-day annual meeting of the Society for the Plastics Industry held in October at Swampscott, Mass.

Morning sessions were held in cooperation with the Harvard Business School, with plastics manufacturers attending in the role of students. Discussion included topics such as labor, pensions, executive development, industrial marketing and advertising. Afternoon sessions centered on the production problems encountered in compression and injection molding. Technical sessions are summarized briefly below.

Compression Molding

Speaking on new frontiers for impact materials, S. M. Silverstein, Rogers Corp., pointed to the plastic fender developed ten years ago under Henry Ford's auspices as an indication of the plastics industry's failure to fully capitalize on the inherent advantages of plastic products. He said the plastics industry must gear itself to thinking in terms of larger pieces; if this pioneering attitude were to be developed, the production of automobile bodies from plastics then envisioned by Ford would soon become a reality.

Dan H. L. Jensen, Philco Corp., explored the future for moldings over 20 lb. Reviewing a number of specific problems which his company had faced in deciding what type of cabinet to produce, i.e. plastic, wood or metal, he showed that the cost advantage of plastics tended to diminish with increased size of cabinet. Other factors taken into consideration were the rate at which the different types of cabinets could be produced and the number of units which must be produced to pay for the tooling costs. He said molders would have to find means to cure larger pieces more quickly in order to reduce the time it takes customers to pay for a tool.

The physical properties of glass-reinforced plastics were the subject of a paper delivered by C. E. Bacon, Owens-Corning Fiberglas Corp. He showed how increasing the volume of glass fibers in a molding from 5 to 35% can increase the flexural strength of the molding from 10,000 psi to 35,000 psi. Tensile and compressive strength follow the same pattern. Bacon also discussed molding techniques which had been used successfully for reinforced plastics and displayed a number of items as examples of the utilization of glass-reinforced plastics. Among these were bread trays, carrying cases, chairs, fishing rods, protective helmets, etc.

Injection Molding

The injection molding session was opened by S. R. Melvin, Monsanto Chemical Co., who spoke on the improvement of thermoplastic products by post-molding treatments. Decoration of plastics by lacquering, silk screening, hot stamping, printing, application of decalcomanias, etc., were discussed. He described the process known as destaticizing which is accomplished by coating an item with a more conductive film which drains the static away so there is no accumulated charge to attract airborne dust particles. Annealing, machining, finishing, metallizing and cementing were also covered.

G. D. Gilmore, Dow Chemical Co., presented an illustrated study of the effects of various injection molding rates on the different heats and pressures needed to operate profitably. His talk was supplemented by pictures of molds being filled under varying conditions. These showed how the material entered and filled out the molding cavity and how the material within the mold distributes itself during the molding cycle.

The advantages to be derived from molding with a preplasticized material as compared with molding by conventional methods were discussed by W. C. Whitehouse, Crown Machine & Tool Co. He cited lower pressures, more uniform heat, less clamp per unit projected area, faster injection speeds, greater projected areas, less tendency for parts to stick in molds, lower mold costs, and less internal stress in molded parts. One disadvantage is that mottling is not possible by the preplasticizing method. Whitehouse said there is seldom any need for pressures over 15,000 psi when injecting with a plasticized material.

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												Flatwise		Edgewise								
						LW	CW	LW	CW			LW	CW	LW	CW	Short Time	Step by Step	As Recd.	Wet	As Recd.	Wet	As Recd.
X	X-13	.0497	1.38	2.0	110	15	12	30	22	42	1100	3.5	2.0	0.70	0.60	750	530	0.039		5.10		0.20
P	XP-13	.0497	1.38	1.5	100	11	10	20	16	26	900			0.60	0.50	575	400	0.036	0.04	4.6	5.2	0.17
	XP-90	.0476	1.31	2.5	45	9.7	7.2	12	10	19				1.00	0.70	600	400	0.055		5.5		0.30
XXP	XXP-13	.0497	1.38	0.9	110	10	8	17	14	27	1000			0.50	0.45	750	530	0.030	0.034	4.3	4.5	0.13
XXXP	XXXP-13	.0497	1.38	0.5	110	9	7.5	16	13	27	1100			0.40	0.35	700	500	0.026	0.028	4.2	4.4	0.11
	XXXP-22	.0466	1.29	0.3	115	12	10.5	13.5	12	27.5				0.379	0.338	810	675	0.024	0.027	4.08	4.2	0.10
	XXS	.0497	1.38	1.5	100	12	10	19	17	34	950	1.1	1.0	0.50	0.45	700	500	0.038	0.042	5.2	5.4	0.20
XX	XX-13	.0497	1.38	0.9	110	12	10	19	17	34	950	1.1	1.0	0.50	0.45	700	500	0.038	0.039	5.2	5.3	0.20
XXX	XXX-13	.0497	1.38	0.7	115	11	10	19	16	36	1200	0.9	0.85	0.45	0.40	650	470	0.034	0.035	4.8	4.9	0.16
	XXARC	.0497	1.38	3.0	100																	
	XXHV	.0497	1.38	1.3	110	10	8	17	15	27	950					600	450	0.033	0.039	4.7	4.8	0.16
	CBW	.0497	1.38	1.9	100	12	10	19	18													
A	A-13	.0614	1.70	0.8	100	10	7	18	16	38	900	1.9	1.8	0.9	0.8	200	120	0.115		5.2		0.60
AA	AA-13	.0560	1.55	0.7	110	10	6.5	19	15	40	1800	5.0	4.1	4.5	4.0	75	45	0.44		6.8		2.99
	MAA	.0639	1.77	5.3	108	7.4	6.5	13	12	45	1300	6.0		4.0		35	27	0.57		13.4		7.7
	FA-72	.0578	1.60	0.7	115	21	17	38	27	48	1400	5.0	4.0	2.5	2.0	70	50					
	MA	.0650	1.80	1.2	115	10	6	17	13	40	900	1.3	1.1	0.85	0.75	150	80	0.11		8.2		0.90
	CF	.0497	1.38	0.8	100	11.5	9.5	22	22	38.5				2.0	1.6	200	125					
C	C-813*	.0497	1.38	1.0	110	11	9	21	19	40	2000	3.6	3.5	2.4	2.1	200	120	0.065		6.0		0.36
	MC	.0524	1.45	3.0	107	9.5	7.9	17	16.6	39				1.4		300	200	0.07	0.17	8.4	15.5	0.59
	CV	.0497	1.38	0.8	115	9	8	20	18	40	2200	2.4	2.3	1.5	1.4							
CE	CE-800	.0497	1.38	0.8	115	9	8	20	18	38	2200	2.4	2.3	1.5	1.4	380	265	0.050	0.058	5.2	5.6	0.26
L	L-400*	.0497	1.38	0.9	110	12	9.5	23	18	39	1900	3.3	3.0	1.4	1.3	200	120	0.065	0.072	6.0	6.3	0.39
	ML	.0524	1.45	2.0	110	13.5	9.1	22	15	39				0.7		325	230	0.07	0.20	8.4	8.95	0.59
LE	LE-13	.0497	1.38	0.7	115	10	8	21	17	40	2000	2.5	2.0	1.5	1.1	450	290	0.045	0.050	4.8	5.2	0.22
	LDC	.0497	1.38	0.6	115	9	7.5	20	16	40	2000	2.5	2.0	1.5	1.1							
	GB-112-M†	.061	1.69	3.0	114	22	20			45						600	400	0.018		7.0		0.126
	GB-112-D†	.060	1.65	2.5	110	33	30			38						900	700	0.018		5.0		0.090
G5	GB-128-M	.0686	1.90	2.2	110	25	22	40	38	50	1700	17.5	16.5	14.0	13.0	500	330	0.013		7.2		0.094
G3	GB-128-D	.0578	1.60	0.6	95	24	15	21	19	44	1500	10.0	7.0	8.0	7.0	600	390	0.025	0.04	4.9	5.3	0.13
G1 & G2	GB-261-D	.0542	1.50	0.6	105	15	11	22	19	39	1200	9.0	5.5	8.0	5.0	425	360	0.011	0.02	4.2	4.3	0.046
	Diamond Dilecto	.0506	1.40	11.0	90	15	9	24	20	38	1000	7.0	5.5	1.5	1.4	600	390	0.055	0.080	6.0	6.5	0.33
	MEC-5	.0423	1.17	0.2	100	6.7	5.7	11	9.5	48	850	5.5	4.0	3.0	2.0	370	340	0.016		4.43		0.071
	GB-112-S	.0614	1.70	.15		19		27		31	960			7.2	5.5	325	300	0.002	.013	3.9	4.6	0.008
	GB-128-S	.0614	1.70	.15		18		23		46	800			12	10	250		0.002		3.9		0.008
	GB-261-S	.0614	1.70	.20		22		24			990			9.5	8.0	150		0.002		3.9		0.008

NOTES: All tests, except "blistering temperature," were conducted in accordance with American Society for Testing Materials Methods for Sheet Electrical Insulation.

*These Grades approximate the physical properties of Celoron.

†These grades are made principally in the thicknesses from .010" to .025". The data shown is for .025" thick sheet.

(1) Flatwise impact test and bonding strength values are based on 1/2" thick material. All other tests are based on 1/8" thick material ex the values for grade XXARC, which are based on 1/32" thick

(2) Wet power factor, dielectric constant, and loss factor values are b on samples which had been immersed in fresh water for 24 ho 25° ± 2° C.

(3) Insulation Resistance values were determined on samples condi for 96 hours at 90% ± 2% relative humidity at 35° ± 1° C.

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How Can Hardness Values Be Used in Metal Design?

by JOHN B. CAMPBELL, Associate Editor, Materials & Methods

Although hardness values can frequently be used to predict various service and fabrication characteristics, they must be used with an understanding of their limitations. This article tells simply and clearly just how far you can trust a hardness value in metals selection and design.

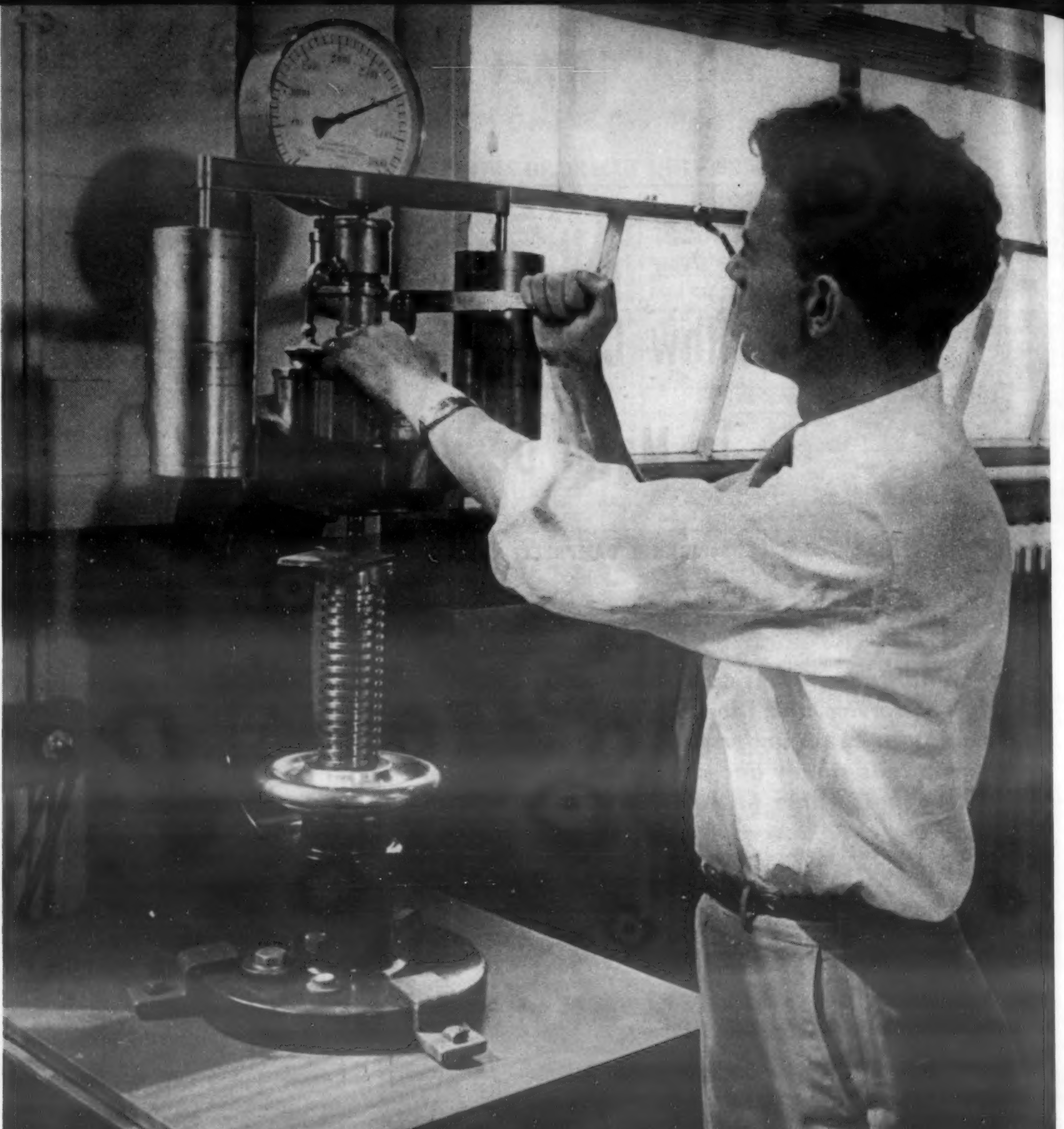
Because of its direct-reading scale, the Rockwell hardness tester is useful not only as a laboratory instrument but also in checking hardness of parts on the production line. (Courtesy Wilson Mechanical Instrument Co., Inc.)

• ALONG WITH THE tensile properties, hardness is probably the most quoted mechanical property of materials. Measuring the hardness of metals is fairly easy. Unfortunately, correct interpretation of hardness values is not always so simple.

One big problem in using hardness values effectively is to curb the enthusiasm of those who see in a hardness value something approaching a universal constant. Like all other mechanical properties, hardness is actually not an inherent property of the material tested, but merely the result of an arbitrary load test performed under standard conditions. Clearly, there must be limits to its physical significance.

As was pointed out in an earlier article on tensile properties (see MATERIALS & METHODS, June 1950, p. 49), the purpose of any set of mechanical properties is to enable the engineer or designer to (1) predict the behavior of the material during fabrication, (2) predict the behavior of structures fabricated from the material under actual service conditions, and (3) compare the material with others for both fabrication and service.

Hardness values alone cannot be used directly to achieve either of the first two objectives. Given a yield strength of 40,000 psi, the engineer knows he must not load a ½-in. rod with more than four tons or it will deform. Given a hardness of Rockwell B 30, the engineer has no immediate information on how the material will behave during processing or service. He knows only that if he runs



Oldest of the commonly used indentation hardness testers, the Brinell machine is still preferred for inhomogeneous material such as cast iron or where deep penetration is desired. (Courtesy E. I. du Pont de Nemours & Co., Inc.)

a Rockwell B test on the material he will get about 30 on the dial—in itself not a very practical bit of knowledge.

Fortunately, hardness values can be related to other more useful properties. Of particular importance is the relationship between hardness and tensile and yield strengths which appears to be especially valid for ferrous metals. These are practical quantities which can be used directly in design.

Attempts have also been made to link hardness values with qualities such as wear resistance, machinability and formability. These attempts have been only partly successful, since each of those properties also depends on a number of other factors not related to the hardness of the material.

Failure of materials and parts to behave in a manner predicted on the basis of hardness values has sometimes led engineers to describe the hardness test as "meaningless." The trouble is that the ordinary hardness value has too often been sold to engineers as a kind of patent medicine to be swallowed upon any pretext. For that reason, this article will attempt to explain simply and clearly the practical meaning of hardness values, and to show to what extent they can be used in metal selection and design.

The Hardness Test

First, what is hardness? No single definition is entirely acceptable. One reason is that there are different kinds of hardness. For instance, hardness of a metal can be measured by denting it, scratching it or bouncing something off it. Obviously, three such different techniques could not possibly measure the same basic characteristics of a material. In the metal-working industries, the first method

has been found most practical and useful. This method is known more formally as the indentation hardness test, and it is the only one that will be considered in this article.

There are three indentation hardness tests commonly used in industry —namely, the Brinell, Rockwell and diamond pyramid tests. Each of these tests involves pressing an indentor into the metal under a certain load for a controlled length of time, then releasing the load and measuring in some way the depression created. The smaller the indentation, the harder the material is considered to be. Therefore, hardness can accurately be called resistance to permanent indentation.

On its face, such a definition says little about the basic mechanical forces involved in the hardness test. But it is clear that during indentation the metal is deformed in compression beyond its yield point and is simultaneously displaced by the indentor. When the load is released, the metal recovers to the extent of its elastic deformation. Thus, at least three different concepts—yield strength, flowability and elasticity—are involved. The relatively complex nature of indentation hardness is the main reason why simple relationships with other properties are hard to find.

Other difficulties encountered in using hardness values are the result of differences among the commonly used tests. It might be well to summarize briefly these differences.

In the Brinell test, a tungsten carbide or hardened steel sphere 10 mm in diameter is used as the indentor. The applied load is either 3000 or 500 kg for 30 sec. After the load is released, the diameter of the spherical impression is measured and the Brinell hardness number found by referring to a chart.

In the standard Rockwell test, either a diamond cone or a 1/8- or 1/16-in. hardened steel sphere is used. First a minor load of 10 kg is applied, then a major load of from 60 to 150 kg. The Rockwell hardness number, read directly, is inversely proportional to the difference in depth between the permanent indentations caused by the small and large loads. Rockwell superficial tests for metal surfaces make use of 3 kg minor loads and major loads from 15 to 45 kg.

The Vickers or diamond pyramid test utilizes a 136-deg square-based diamond pyramid as indentor and a load of from 1 to 120 kg. In this test, the diagonal of the impression is measured. This measurement is carried out on the machine and translated into a DPH number by means of a table.

Some General Limitations

One of the important decisions an engineer must make in evaluating a set of hardness measurements is whether the proper test and equipment have been used. The choice depends on a great many factors. Most important are: size, shape and thickness of the test piece; composition and structure of the metal, hardness of the metal, surface conditions, accuracy requirements and the quantity of work to be tested. Since these conditions often conflict with one another, the choice is not always an easy one.

However, some generalizations can be made. With a 500 kg load, the Brinell test is satisfactory for aluminum and copper alloys, but with a 3000 kg load it is limited to steels with tensile strength between 75,000 and 250,000 psi. Using the Brinell tester on steels having tensile strength greater than 300,000 psi (600 Bhn) may produce permanent deformation of the ball, causing subsequent determinations to be inaccurate. An inhomogeneous material such as cast iron is usually tested by the Brinell method, since the impression is large enough to average the wide variations in hardness and thereby give good reproducibility. For the same reason, the Brinell test is suitable for rough forged surfaces.

The Rockwell test is more flexible than the Brinell as it can be used on harder materials and thinner sections. For steel of 150,000 psi tensile strength, the minimum thickness which can be tested by the Brinell method is 0.15 in. whereas for the Rockwell test it is less than 0.05 in. Since hardness numbers can be read directly on the Rockwell machine, it is widely used for routine testing where large quantities are involved. In addition, the small impression left by the Rockwell test is not as likely to spoil surface appearance. Because of the shape of its indentor and the accuracy of its impression-measuring device, the DPH test is the most accurate of the three principal indentation methods.

Granting that each hardness test has its place, it is desirable for practical purposes to know the relationships among the various hardness scales. These relationships are not too definite. Good conversion charts are available for steel and brass but, in general, hardness scale conversions are approximate at best.

There are two main reasons for this difficulty. One is that the metal being tested changes in hardness, becoming more resistant to deformation as penetration increases. The extent to which this occurs varies from one material to another, depending on differences in cold-working characteristics and in the degree of prior cold-working. Another reason is that any test which depends upon depth of penetration must be influenced by the amount of elastic springback which occurs when the load is released. This effect depends upon modulus of elasticity which differs for each group of alloys. In addition, both strain hardening and elastic springback depend upon the particular indentation test used. Strain hardening is influenced by the rate of load application. As for elastic springback, it is clear that the Brinell and DPH tests which measure lateral surface dimensions would be less affected than the Rockwell test which measures depth.

A complete discussion of the limitations of the hardness test is not necessary here. But two other factors deserve mention:

1. Since surface layers are often hardest due to cold working during fabrication, tests which involve the least penetration generally give highest hardness values. In many cases surface effects can be minimized by grinding until the hardened layer is only a small part of the layer penetrated by the indentor.

2. In any test which measures hardness by depth of penetration, hardness values for soft metals are likely to be further off than values for harder metals. This is because the constant percentage error in the testing equipment applied to greater penetrations produces greater numerical deviations. However, this characteristic is of little practical importance since such errors are insignificant compared to the hardness range permitted by most specifications at the lower hardness levels.

It is not enough to take all these factors into account. When the engineer tries to use hardness values to predict more useful design properties he runs into even more trouble. Most often he is interested in the relationships between hardness and strength, wear resistance, machinability and formability. The rest of this article will be concerned with these relationships.

Hardness vs. Strength

Not so long ago it was stated in a technical article that "hardness defines satisfactorily all the other sig-

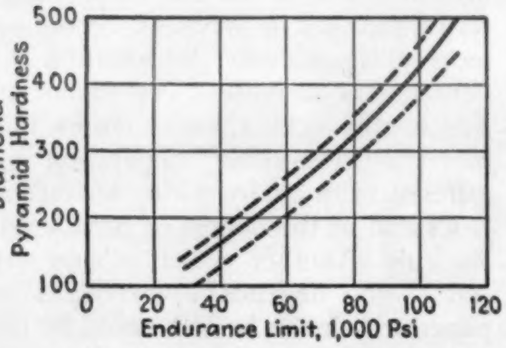


Fig. 1—This correlation between diamond pyramid hardness and endurance limit of hot-worked steels is an approximation and should be used with extreme caution. (Adapted from "Metals Handbook")

nificant mechanical properties of a steel member." This is a good example of that over-exuberance mentioned earlier. Actually, the relationship between hardness and the tensile and yield strengths of steel is fairly well established, but the relationship with endurance limit is shaky at best and there is no generally accepted relationship with impact strength. For nonferrous metals these relationships are even less advanced.

It is not hard to see from the nature of the indentation test that hardness is somehow connected with compressive yield strength. Since experience has shown that for most carbon and low alloy steels there is a close relation between compressive and tensile strengths, it is not surprising that there should be a relation between hardness and tensile strength.

The most generally accepted approximation follows: when the Brinell hardness of a steel is between 200 and 500, its tensile strength in psi can be estimated approximately by multiplying the Brinell hardness number by 500. Generally such an estimate is accurate within ± 5000 psi, and errors greater than $\pm 10{,}000$ psi are unusual. Thus, a steel of 400 Brinell hardness would be expected to have a tensile strength of about 200,000 psi; the conservative designer might knock this down to 190,000 psi to be on the safe side.

For Rockwell values, somewhat more refined equations have been developed by Petrenko:

$$\text{Tensile Str (Psi)} = \frac{4{,}750{,}000 - 12{,}000\ R_B}{130 - R_B}$$

$$= \frac{10^5\ (7000 - 10\ R_C)}{(100 - R_C)^2}$$

The first equation is for steels with tensile strengths between 80,000 and 120,000 psi (82 to 100 Rockwell B), and the second is for tensile strengths from 90,000 to 190,000 psi (10 to 40 Rockwell C). Both are accurate within 15%. Thus, a steel of 90 R_B would be expected to have about 92,000 psi tensile strength. And tensile strength of a 30 R_C steel would run about 137,000 psi.

A simpler relation in terms of the DPH scale has been proposed by Gray and Scott. In this case, tensile strength of steel can be estimated by:

$$\text{Tensile Str (Psi)} = 494\ (\text{DPH}) - 7000$$

This applies only where hardness falls in the range of 200 to 660 DPH. According to this equation, a steel having 500 DPH would have a tensile strength of about 220,000 psi.

For cast iron the picture is not so simple. The relationship between hardness and tensile strength is definitely not a straight line and deviations from the best-fitting curve are much more extensive than in the case of steels. This can be attributed to the greater variations in microstructure which are likely to occur in cast iron. A recent equation derived by J. T. MacKenzie may be helpful as an approximation:

$$\text{Tensile Str (Psi)} = 1.82\ (\text{Bhn})^{1.85}$$

Thus a cast iron of 300 Bhn might be expected to have a tensile strength in the neighborhood of 70,000 psi. This equation does not hold for white irons. Predicted tensile strengths tend to be too high for irons containing over 2 copper, 3 nickel or 1% phosphorus unless they are well-balanced or heavily inoculated. Other investigators have shown that in a relation of this kind predicted strengths tend to be on the low side for inoculated irons, on the high side for untreated irons and just about right for stabilized irons.

It is always a little dangerous to talk about definite relationships with endurance limit or fatigue strength. This property is extremely sensitive to heterogeneity of the metal, quality of surface finish and presence of residual stresses. These conditions must be specified closely before an endurance limit value is of any practical use. For instance, Fig 1 (adapted from "The Metals Handbook") gives a relationship between diamond pyramid hardness and endurance limit. It is important to note that this relationship applies to "high-quality hot-worked steels when properties are varied by tempering temperature or carbon content chiefly, and when the steels are fully hardened to the martensitic condition before tempering." As would be expected from the tensile strength relationships discussed above, this relation is close to a straight line. However, extreme care should be used in working with such a curve.

It is often assumed that within the practical range the harder a metal the more brittle or less tough it is. In comparing two materials of about the same composition and structure, such an assumption often proves valid. But in general there seems to be no basic relation between hardness and toughness, as both are influenced by cohesive strength, shear strength, ductility, etc. Variation among the various toughness tests—Charpy and Izod impact, static bend, and torsion impact—is another complicating factor. The different means of loading in these tests result in different proportions of cohesive strength, shear strength and ductility being measured. However, these tests often show a general tendency for toughness to increase as hardness decreases.

Hardness vs. Wear Resistance

The possibility of establishing some definite relationship between hardness and wear resistance of metals has long been attractive to the engineer. Offhand it might seem that the harder a metal, the more resistant to wear it would be. Within certain limits this is certainly true; if it were possible to control all other factors contributing to wear resistance, it might be found that wear resistance is directly proportional to hardness. However, such a generalization is of little practical value.

Wear itself is an elusive property. There are at least five or six different types of wear and each is produced in a different manner. When a metal surface rubs against a harder surface, cutting wear occurs. Other factors equal, the rate of metal removal certainly increases as the difference in hardness increases. But a much more important factor is the smoothness of the harder surface; if it is smooth enough practically no wear will occur. The other type of wear most obviously related to hardness is abrasive wear. This occurs when a metal surface is exposed to scratching by hard particles, loose or imbedded in another surface.

Composition and structure of the metal also play an important part. For example, given two steels of equal hardness, one containing 5 to 15% chromium will have two to three times the wear resistance of the other. And although some hardfacing metals are relatively soft (averaging 25 to 50 Rockwell C) compared with hardened alloy steel (60 to 68 Rockwell C), their wear life is two to ten times greater because of the hard

carbides imbedded in the matrix.

The latter case underlines the importance of the difference between mass hardness and point (micro) hardness. Because the area of the impression is great enough to cover several grains, the indentation hardness test measures what might be called mass hardness. But in the case of the hardfacing material mentioned above, microhardness has a much greater effect on wear resistance.

In general, hardness values do not provide a reliable index for estimating wear except where results are compared for metals of the same composition. Only then is it safe to say that wear resistance of a metal increases with its hardness.

Hardness vs. Machinability

Engineers often want to know something about the machinability of a metal, and a set of hardness values sometimes seems like a convenient shortcut. Unfortunately, both hardness and machinability are too complex to be related in any simple manner.

For instance, what is machinability? An adequate answer cannot be brief; there are too many criteria of practical importance in the machine shop. According to one authority, there are five different aspects of machinability: the cutting speed-tool life relationship, surface finish, the power requirement, chip formation and dimensional stability. Suppose that for a tool life of 90 min, steel A can be cut 10% faster than steel B. In that respect, at least, steel A is more machinable than B. But suppose the chip from steel A is long and stringy whereas the B chip is short and clears easily. The tool will foul more often on A, and its machinability in this respect is less than that of B. Add in the other three factors and the complications are obvious.

These criteria of machinability depend on metal properties which are not necessarily reflected in the indentation hardness test. It is not strange that there should be attempts to link hardness and machinability, as penetration of the metal is certainly involved in any cutting action. However, machinability depends not only on resistance to penetration but also on resistance to the flowing aside of the chip element and, for a ductile metal, on work-hardening ability. Under such circumstances, it is too much to expect the hardness value to qualify as a reliable single index of performance.

Although hardness seems to fail as a control index for machinability, it is still important and cannot be neglected in selecting cutting conditions for a specific job. Therefore it is desirable to have some way of compensating for changes in hardness even though the method may be empirical and the results only approximate.

The latest approach to this problem is scheduled to appear in the new edition of the "Manual on Cutting of Metals" to be published next year by the ASME. It will be a graph of Brinell hardness versus relative machinability in percent (based on B1112 steel rated at 100%). These relative machinability ratings have been determined for nearly 300 steels representing a wide range of compositions, microstructures and hardnesses. The relationship is almost a straight line; in other words, relative machinability appears to be almost inversely proportional to Brinell hardness. If reliable cutting conditions are established for several representative hardnesses, then the cutting conditions for a specific hardness can be found by correcting the reference conditions for the next higher reference hardness. This method will result in somewhat conservative cutting speeds.

The relationship described above should not be taken as an indication that machinability invariably increases as hardness decreases. As a matter of fact, the machinability of low-carbon steels is often improved by cold working to increase both hardness and toughness. And the machinability of copper alloys is often improved by including specific "hardening" elements in the composition.

Another recent approach to the problem of predicting machinability, and one that holds much promise for the future, is that developed by Merchant and his associates. By means of microhardness tests on machined chips they have found that the amount of strain hardening occurring in a metal during chip formation has considerable influence on the wear of the cutting tool. Thus, it may be possible to relate machinability to various physical properties which reflect the work-hardenability of the metal.

Hardness vs. Formability

Another field where hardness values are important is in predicting the behavior of metals during forming operations, especially deep drawing. Again, hardness is only one of many factors which should be taken into account, but in practice the engineer is often forced to rely heavily upon it.

The two most common tests for deep-drawability are the Rockwell hardness test and the cupping test. Elongation and reduction of area, as shown by the tensile test, also measure ductility; but the cupping test is more indicative of performance under actual deep-drawing conditions. It can be said in general that the higher the ductility and the lower the hardness, the more a material can be deformed without fracture.

Many plants dispense with ductility tests entirely and rely upon the hardness test alone. However, it has been found that hardness values are not always indicative of drawing or forming behavior. They are much more meaningful when coupled with a knowledge of the chemistry and processing of the metal.

For example, the forming properties of a normalized sheet of 40 Rockwell B hardness are not necessarily the same as those of a box annealed sheet at the same hardness level. Therefore, to say merely that a steel sheet contains 0.08% carbon and measures 40 Rockwell B does not give a good indication of drawing quality. To say that a steel sheet contains 0.08% carbon, was finished off the hot strip mill at 1600 F, cold reduced 60%, box annealed at 1300 F, temper rolled ½% and aged 30 days, and has a Rockwell hardness of B40, gives a much better idea of the drawability of this material.

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Flexible, Corrosion Resistant Plastic Solves Gasket Problems

by B. G. STAPLES, The Pfaudler Co.

Teflon rings and tape prove good gasket and gasket-protecting materials for use in chemical processing equipment.

• FOR MANY YEARS, the Pfaudler Co. has been seeking a material as resistant to chemical attack as glass but having physical properties similar to those of yielding rubber. The goal was a gasket material which could be used at joints in the glass-lined and stainless steel equipment manufactured by this company for the chemical, dairy, food, beverage and other processing industries.

Although this objective has not yet been attained completely, it has been approximated after some six years of experimental work with polytetrafluoroethylene plastic known commercially as Teflon. This plastic is one of the most inert to chemical attack, and can be used at temperatures up to 500 F without decomposition. Though less yielding than rubber, it has a sufficient degree of compressibility to serve as a gasket for some applications; in other cases it can be used in combination with a softer core of asbestos or with corrugated metal rings. Moreover, Teflon lends itself to certain molding and machining operations by which it can be used to make tight joints on pressure vessel covers and in other fittings where flanged joints are required.

In early Pfaudler applications, Teflon tape 0.004- to 0.005-in. thick was wrapped spirally around gaskets made of woven asbestos, which was thereby kept out of direct contact with chemicals. Such gaskets produced joints that were sufficiently tight under moderate pressures and satisfactory for some uses. Some are still in service after five years.

It was found, however, that the many overlapped joints in the spiral wrapping permitted some seepage under high pressure, and joints of this type could not be shimmed in the field. Further experience indicated that rings machined from molded Teflon tubes (Fig. 1) could be used at pressures up to 300 psi, but the size of tubes available was limited to a 20-in. dia maximum; hence, gaskets of larger outside diameter had to be made in some other way.

Gaskets good for pressures up to 300 psi can be made from strips of Teflon tape having 0.015-in. thickness and width about twice that of the face of the ring to be formed. This strip stock is folded longitudinally over a core that consists of a ring cut from hard, laminated sheet asbestos for strength and covered on both sides with thin layers of asbestos felt for compressibility and thermal insulation. If pressure is to exceed 125 psi, the inner core of laminated asbestos is replaced by a ring of corrugated steel.

Before this plastic strip is assembled in gasket form, it is molded to fit the flat, annular filler over which it will be placed. Molding shapes the plastic enough to prevent wrinkling of the flat faces, and is accomplished by running the strip through a heated die (Fig 2). The process is applied to successive lengths of about 6 in. at a time, until the whole ring is shaped without cutting the strip except for total length. The shaped annular envelope or shield would fit the core ring with some overlap at its ends. At the overlap, therefore, the plastic is fused in a die in an arbor press (Fig 3) so that there can be no leak at this single joint. Then the flexible envelope is placed inside and over the core ring and the gasket is ready for use. Several such gaskets are shown in Fig 4.

Fig. 1—Parting tool in a lathe is used to cut an annular ring gasket from the end of a molded tube of Teflon.

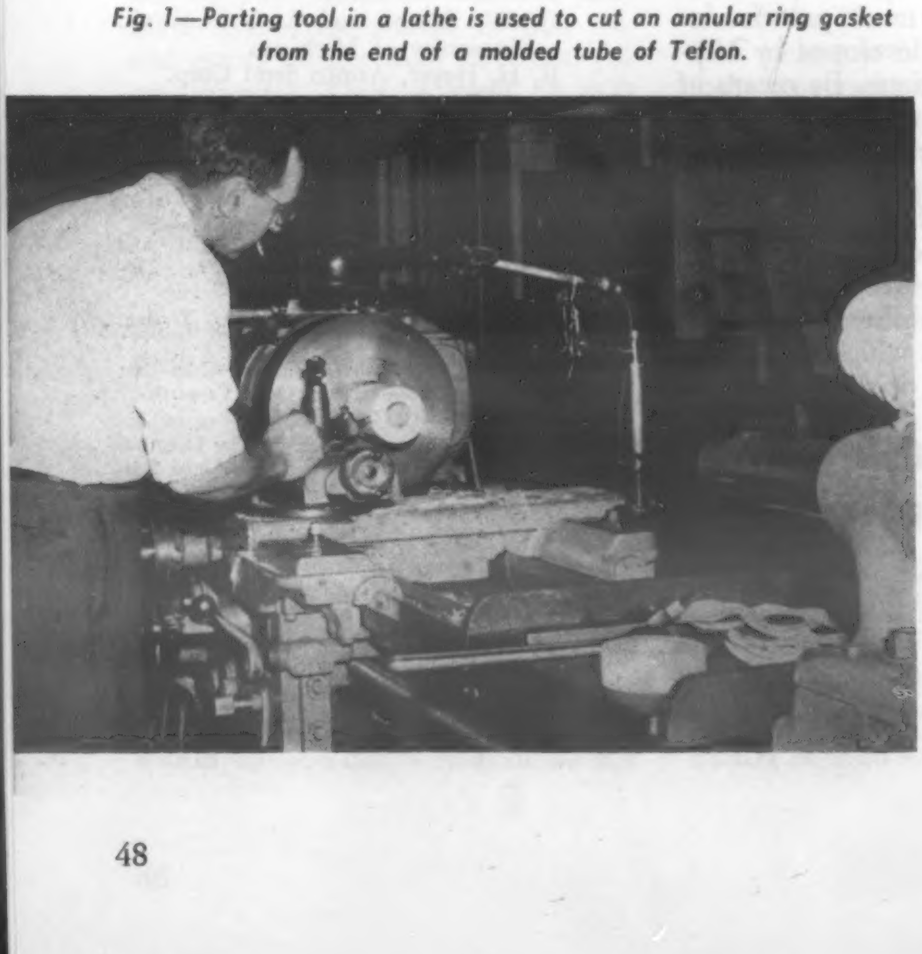


Fig. 2—Folded Teflon tape is run through this heated die to shape an envelope for an annular core of asbestos or metal.

Cover plate for a large processing tank is lowered onto a Teflon-protected gasket.

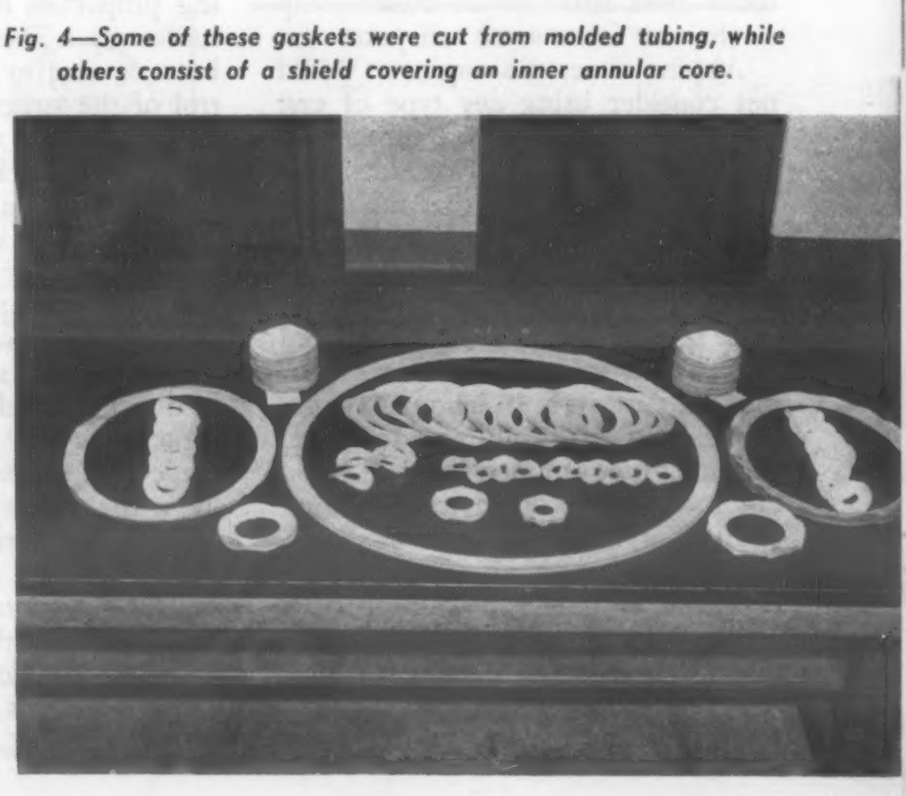
Since the fold in the tape is at the inside of the ring, the core does not come in contact with the liquid or gas sealed inside, and the shield is endless. Gaskets of this type have been made with outside diameters from 19 to 89 in. with excellent results.

Another use for Teflon is in small rings or washers that are used to patch or cover holes in the glass lining of tanks. Such flaws are often barely visible to the eye, and are located only by applying a 30,000-v potential to a tool which is run over the entire inner surface of the lining. If a flaw exists, the high voltage spark jumps through to the grounded steel shell and reveals the defect.

When a flaw is thus located, the glass is cut away with a tiny carborundum wheel and the metal shell is drilled and tapped at that point. A tantalum screw projecting through a small Teflon washer is then put in place. As the screw is tightened, its head presses the Teflon tightly against the glass lining around the tapped hole so that corrosive fluids in the tank cannot reach the metal shell.

Fig. 3—After a suitable length of Teflon tape is shaped, the overlapping ends are fused together in this heated die to produce an endless shield.

Fig. 4—Some of these gaskets were cut from molded tubing, while others consist of a shield covering an inner annular core.



Engineering Properties of Iron Castings Can Be Improved by Heat Treatment

The uniformity of Meehanite iron castings makes them especially suitable for through-hardening as well as local or surface hardening operations.

by C. E. HERINGTON, Meehanite Metal Corp.

• ONE OF THE most useful and possibly basic materials of construction in engineering components in the past has been cast iron. Cast iron has received a tremendous amount of attention from research workers in this last decade and we now find that it has not fallen into discard as has been predicted, but has actually been produced in larger and larger tonnages. This is because of its characteristics in engineering construction and the comparative ease with which it can be produced and the tremendous improvements that have taken place in its manufacture and control and resultant properties. In fact one would be quite safe in stating that the modern controlled cast irons as produced today bear little or no relationship to the cast irons some ten years ago.

At one time, the engineer would not consider using any type of cast iron for a highly stressed component and, in fact, his lack of confidence in the material was such that the safety factors used in design often prohibited its use because of the terrific weight involved. Today, however, these safety factors have been reduced considerably in so many instances that modern cast iron is being used extensively in cast crankshafts for diesel and other type engines, pressure work, die manufacture, presses, mining equipment, etc.

Changes in design made to increase efficiency or reduce machining costs are more readily accomplished with castings. For example, when a unit requires steam, air or water passages within the part, castings can meet these demands most efficiently even in cases of intricate design. Steam heated dies, water-cooled cylinders, diesel engine heads can be cast successfully and with an assurance of uniform density and solidity. The Meehanite quenching dies shown here were used to hold steel airplane propeller blades during a quenching operation. The dies were cored to allow the circulation of cooling water to flow through them.

One of the features of the manufacturing techniques applied in the production of Meehanite castings is the ability to control the weakening influences of sectional changes and so regulate the metal in relation to the casting section that the engineering properties required are achieved uniformly. These techniques have been devised to permit accurate control of the structure of the solidified metal and it is this control of structure, not just chemical composition, which results in an equal control of the mechanical characteristics of the casting.

The microscope quickly reveals the importance of structure by the relation of tensile strength of materials in direct parallel with the basic constituents of the material and the arrangement of them. The illustrations show the varying structures of four common and widely used materials; a standard low carbon steel casting, an all-pearlitic tool steel, a soft gray cast iron and that undefinable and illegitimate child of the foundry industry which is described as "semi-steel."

These facts are of major importance to the user of iron castings since in the past the fear of hidden structural defects, porosity, and low strength properties has been a detriment in the minds of many engineers and designers.

To understand the difference between Meehanite metal, ordinary cast iron and cast steel, it is necessary to examine some factors which influence the mechanical and physical properties of these materials.

The composition and structure of ordinary cast iron is, more or less, indeterminate and for this reason it is frequently not suitable for the high standards set in modern engineering practice. During solidification in the mold, cast iron becomes a mechanical mixture of graphite in a base matrix consisting of a number of constituents. The flakes of graphite in the matrix, are in reality thin saucers which occur in all planes and intersect one with another to form continuously interlocking structures through which fluids can seep even at normal low pressures. The flakes lie at all angles and in all directions and in the softer grades of gray cast iron, the graphite occupies from 10 to 13% of the volume of the casting.

Note the distribution of graphite in ordinary cast iron. From this may be judged the effect of the continuous interlocking form of the graphite structure upon the mechanical properties and solidity. Note the difference which results from the control of the size and shape of the graphite as achieved in a Meehanite casting.

Heat Treatment Improves Properties

As a result of these structural controls and the uniformity which is achieved by them, Meehanite castings have shown outstanding reactions to the various standard forms of heat treatment, and they may be fully hardened by various quenches and draws, and in addition may be subjected to flame hardening for local or surface characteristics.

Tensile strengths above 75,000 psi and Brinell hardness up to 500 can be achieved by oil quenching from 1600 F while a flame hardened surface will approach 600 Brinell to a depth of case from 1/8 to 3/16 in. In addition to the values illustrated, toughness is substantially increased with the attainment of Charpy impact values above 10 ft-lb if the material is subjected to drawing or tempering at about 750 F for several hours. As a result of these sharp improvements in design and engineering characteristics, there has been a great deal of investigation with regard to the effect of heat treatments of Meehanite castings and the possible new applications which might be developed.

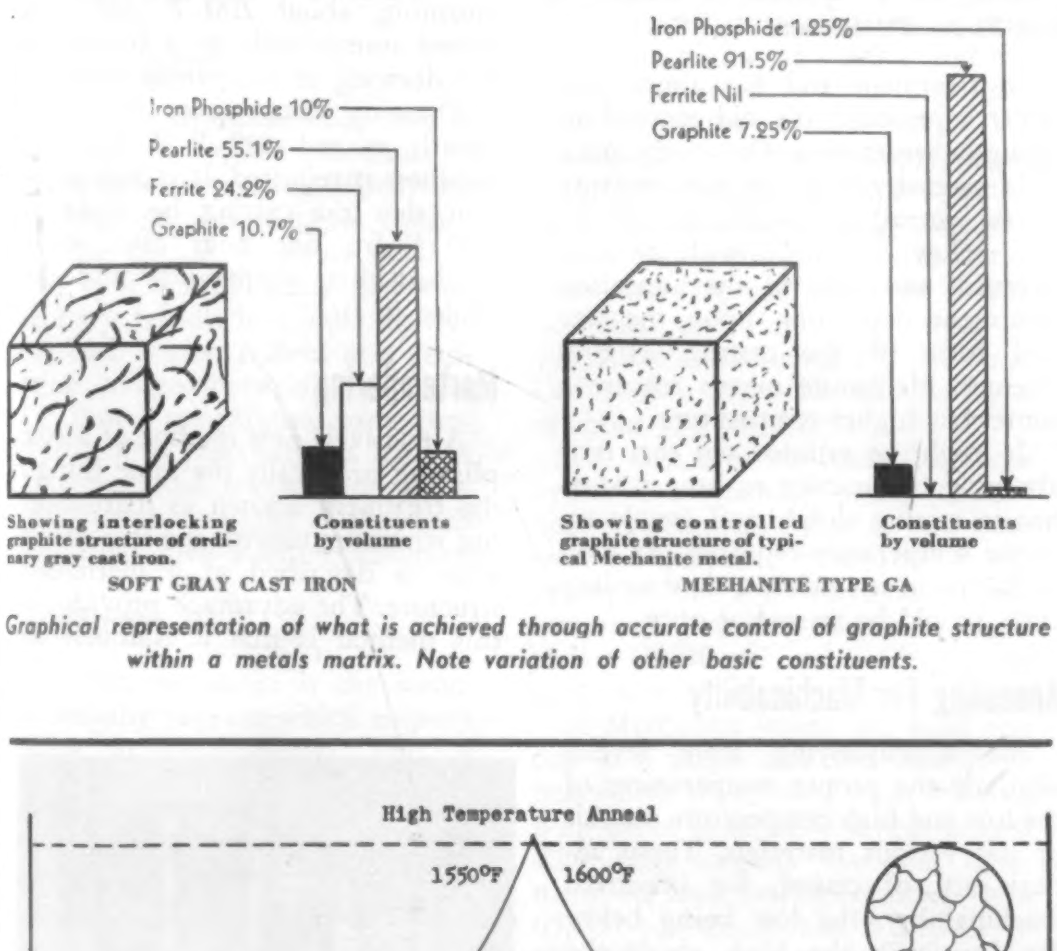
Because of the structural constitution of these materials, heat-treated castings can result in substantial cost savings, improved production efficiency and, of course, increased service life.

Much research over the years has been devoted to 6 basic heat treatments which are commercially applicable, and considerable work has been done to establish the so-called "critical" temperature range as far as Meehanite metal is concerned.

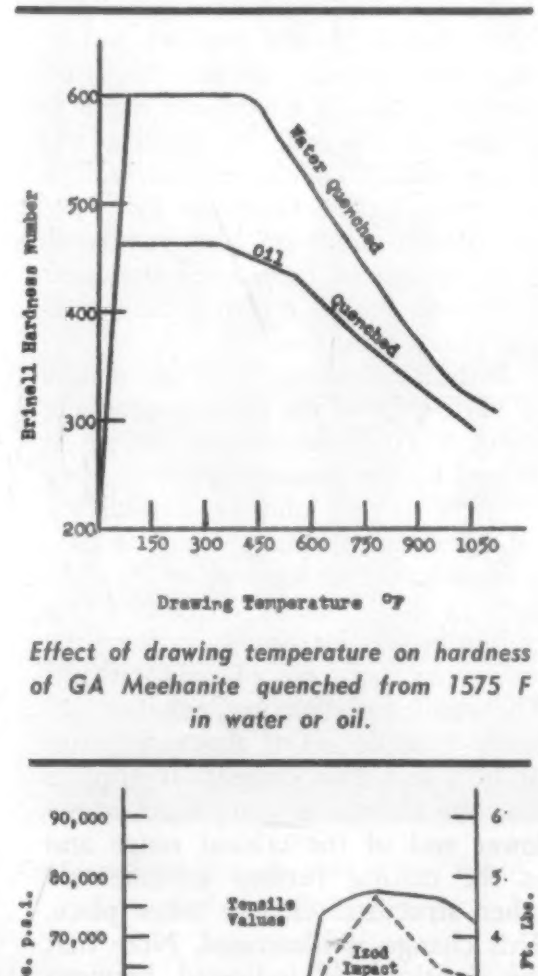
Maximum uniformity of structure as described before is always important else the effects of any heat treatment might be partly nullified. For these reasons the foundryman should know in advance if a casting is to be

Type Meehanite	Temperature °F.	
GE--GD	950--1000	
GC--GB	1050--1100	
GA--GM	1100--1150	
Recommended Temperatures for Improved Machinability		
Type	Low Temperature Anneal °F.	High Temperature Anneal °F.
GE--GD	1220--1260	1550
GC--GB	1230--1270	1570
GA--GM	1250--1290	1580

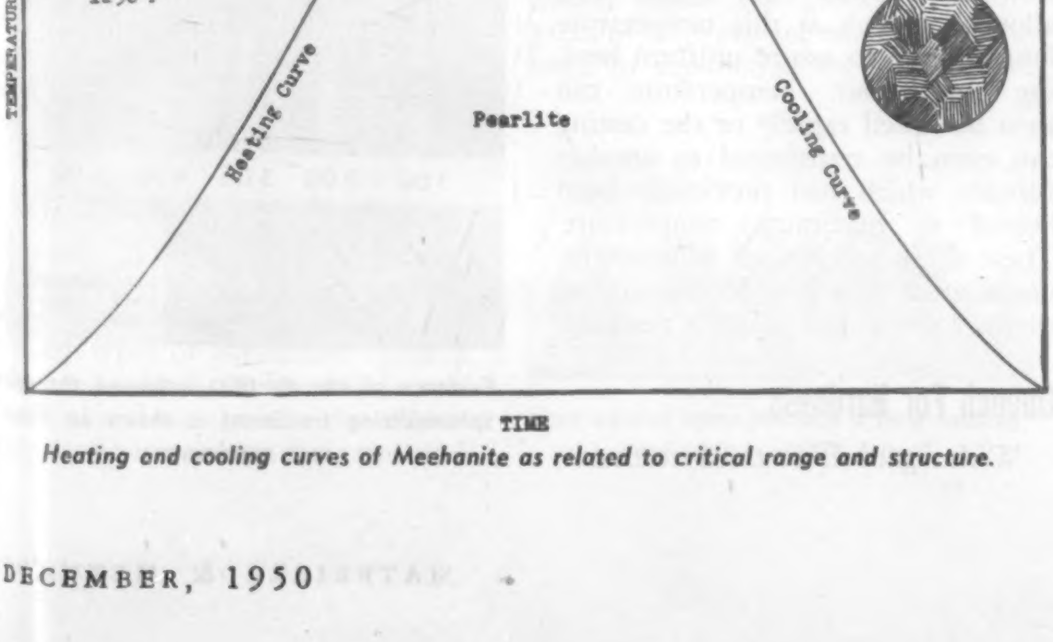
Recommended temperatures for stress relief.



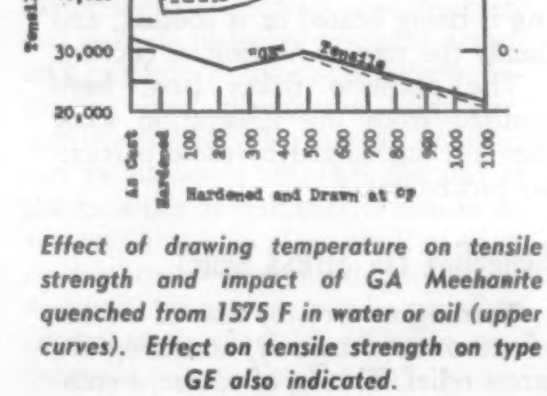
Graphical representation of what is achieved through accurate control of graphite structure within a metals matrix. Note variation of other basic constituents.



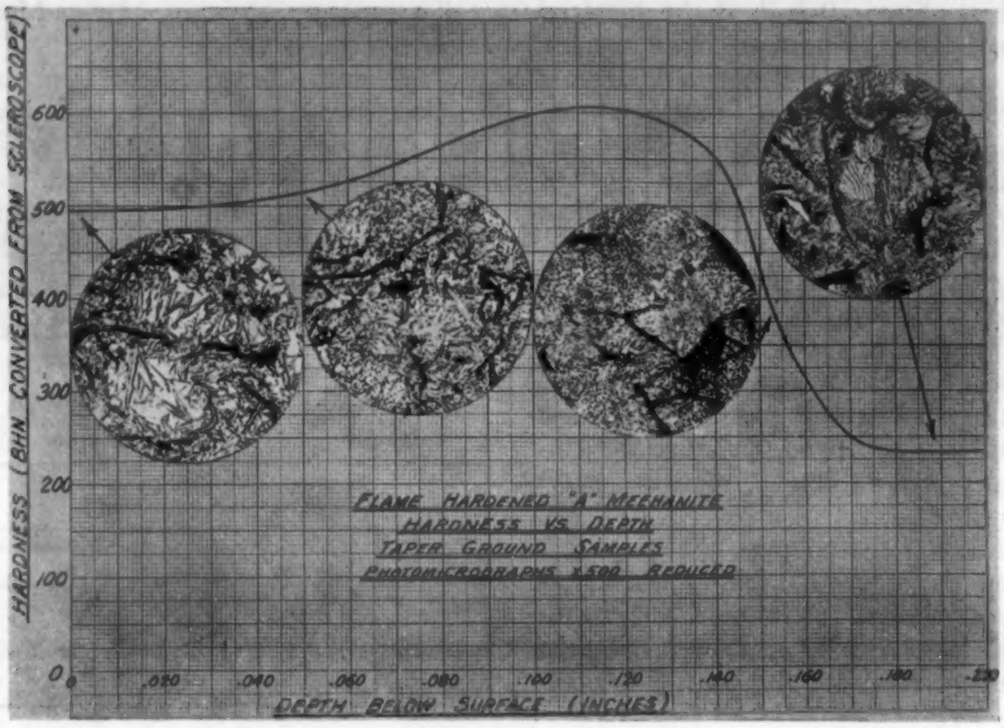
Effect of drawing temperature on hardness of GA Meehanite quenched from 1575 F in water or oil.



Heating and cooling curves of Meehanite as related to critical range and structure.



Effect of drawing temperature on tensile strength and impact of GA Meehanite quenched from 1575 F in water or oil (upper curves). Effect on tensile strength on type GE also indicated.



Relation of hardness and to depth of flame hardened Meehanite Type GA.

heat treated by any method and in Meehanite foundries when this is established special efforts are made to achieve a material of density and purity with particular effort to eliminate free ferrite. Graphite flake size and distribution are also regulated. It is, of course, recognized that heat treatment does not turn a poor casting into a good one.

In heat treatment, it is the matrix or basic mass of the casting, generally about 9/10 of its volume, which is altered by the process. After pouring an iron casting and as the casting solidifies, the matrix is made up of a solid solution of carbon in iron. As soon as the "critical" is reached this carbon begins its separation from the matrix in the form of iron carbide. The resulting structure, pearlite, actually is made up of alternate plates or iron and iron carbide. It appears that the change is completed at the lower end of the critical range and as the casting further solidifies no other structural change takes place. This change is illustrated. Note that the "critical" is indicated between 1300 and 1450 F. The exact position of the range naturally depends upon the type of Meehanite metal (either low or high carbon) whether the casting is being heated or is cooling; and finally the rate of heating or cooling.

The graphite flakes have been omitted from the illustration since they are unchanged by these particular procedures.

Annealing For Stress Relief

Turning now to the first of the list of treatments; namely, annealing for stress relief. This is, of course, a common treatment and has almost entirely superseded the old method of aging or weathering. Obviously, since it is necessary to retain the structure of the metal, temperatures must be kept below the critical, with the temperature and time of the annealing treatment depending upon the size and form of the casting. Higher strength Meehanite metals require a somewhat higher temperature.

It might be pointed out that it is always good practice to heat a Meehanite casting slowly and evenly up to the temperature required. As soon as this point is reached a slow cooling cycle should be started at once.

Annealing For Machinability

An accompanying table reveals similarly the proper temperatures of the low and high temperature anneals of the various materials. These anneals are, of course, for improved machinability, the low being below the "critical"; the high above the critical range. When using the high temperature treatment it is recommended that the castings be heated slowly to around 1200 F and then allowed to soak at this temperature long enough to assure uniform heating throughout. Temperature can then be raised rapidly or the casting can even be transferred to another furnace which had previously been heated to maximum temperature. These slight precautions will contribute a great deal toward eliminating thermal shock and possible cracking.

Quench For Hardness

With regard to the third treatment; namely, heating and quenching for hardness, most of the general engineering types of the material are closely comparable to carbon steels in their reaction to hardening by quenching in water or oil from above the critical. In such cases, after soaking at about 1200 F, the temperature is raised to about 1600 F and the casting is then ready for hardening by quenching in oil or in water. With the exception of simple and uncomplicated castings, it is generally preferable to quench in oil or warm water so as to minimize the chances of cracking. It follows, of course, that the more drastic the quenching the greater possibility of internal stresses being created which might result in cracking. For this reason it is advised that the casting be withdrawn from the quenching medium while still steaming, about 200 F, and transferred immediately to a furnace for the drawing or tempering operation.

Drawing temperature should not greatly exceed 400 F if maximum hardness is required. It is also important that the casting be soaked at 400 F for one hour after it has reached that temperature and then cooled in air.

Martempering

A relatively new method of accomplishing practically the same thing is the treatment known as martempering which transforms the structure to what is described as a martensitic structure. The advantage provided by this method is that it is much less

Evidence of the ductility achieved through spheroidizing treatment is shown on these test specimens.

severe in creating internal strains. The casting is quenched rapidly from above the critical by submerging it in a liquid bath and held at a temperature of about 500 F. It is held in the bath only until the casting has reached the same temperature as the quenching medium. It is then withdrawn and cooled in air. Generally a low temperature draw can be used to further reduce any tendency toward cracking, particularly if the casting shape is intricate.

The effect of drawing temperature on the tensile and impact strengths of the same material is shown graphically. This illustration also shows that the lower strength, high carbon materials, of which Meehanite type GE with an as-cast tensile of 30,000 psi is typical, may actually be weakened by a quench and draw treatment.

Interrupted Quench

The fourth treatment adaptable is described as interrupted quenching or occasionally austempering. Briefly the process consists of holding the casting above the critical at about 1600 F until it is uniformly heated and then plunging it rapidly in a liquid salt or a lead bath which is held at a temperature range between 500 and 900 F. Lower temperature baths provide structures practically as hard as the conventional quench and draw but considerably tougher. Higher bath temperatures give a softer structure.

Spheroidizing

The fifth treatment is the somewhat lengthy process which imparts ductility to the material. This is known as spheroidizing in which the casting is submitted to a prolonged heating at a temperature below the critical point. Experiment has determined that 1300 F is the minimum for the higher types of Meehanite metal with the maximum results being obtained by holding it at this temperature for five hours upward. This treatment, however, gives hardness only in the range of about 180 Brinell. The practical aspects from the application standpoint of the resulting material have not been fully exploited.

Flame Hardening

Local flame hardening, where facilities are available, has been applied to many types of Meehanite castings and the results have been definitely beneficial and worthwhile. An accompanying figure shows the structural changes of a flame hardened surface, the transition zone and base metal of a Meehanite casting and also the hardness as related to depth below the surface.

With this method the zone of maximum surface hardness obtained is usually ½ to ¾ of the total depth of the case and is file hard. The success of the flame hardening operation is, of course, basically dependent upon the uniformity, density and constitution of the material and that is why little work of this type has been done on the average gray iron casting.

A few typical examples will be given to show the results obtained by the various heat treatments described above.

A diesel engine liner produced to the American Bureau of Shipping Specifications was annealed after rough machining at 1200 F and the casting provided a Brinell of 225 after the treatment.

Cams are a good example of an application requiring both abrasion resistance and toughness in combination with machinability. The parts were heat treated to 1600 F and quenched and drawn one hour at 400 F after machining and grinding. Cam surface thus achieved a hardness of about 375 Brinell.

The cast ram and ram tip, for a hydraulic briquetting press, replaced heat treated steel forgings and both were oil quenched from 1600 F and drawn at 1000 F for three hours. This treatment provided tensile strength above 70,000 psi and a Charpy impact value of around 8 ft-lb.

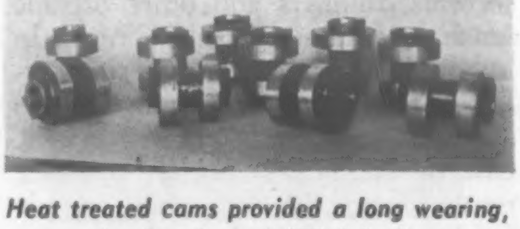
A Meehanite worm and shaft was cast as a single unit and used for a heavy-duty drive on a sugar refining pulp press. It replaced a heat treated alloy steel forging. The heat treatment on this casting resulted in a 65,000 psi tensile and a Brinell of 350. Here the treatment consisted of quenching in oil at 1600 F and drawing at 900 F for 60 min.

A rather unusual application is in thread gages, for generally thread gages of all types are made from tool steel. In production these gages are preheated after rough machining operations to a temperature of 1200 F and transferred to a high speed furnace and brought up to a temperature of 1600 F. They are then quenched in cool oil. No drawing operation is required.

After heat treating, centers are lapped and the gages finish ground to the major thread diameter. Finally, the threads are rough and finished ground.

There seems little question but that in spite of the evidence of the benefits available through the proper application of various heat treatments to iron castings, that neither the specifying engineer nor the producing foundrymen have given proper attention to the subject. Modern foundries utilize up-to-date production equipment and manufacturing controls yet frequently fail to study properly customer design and property problems. Similarly, engineers and production men frequently fail to give thought to what can be achieved through the use of the facilities of commercial heat treating organizations. As a result of these double oversights, production time and product quality may be sacrificed or improper material selection may be made.

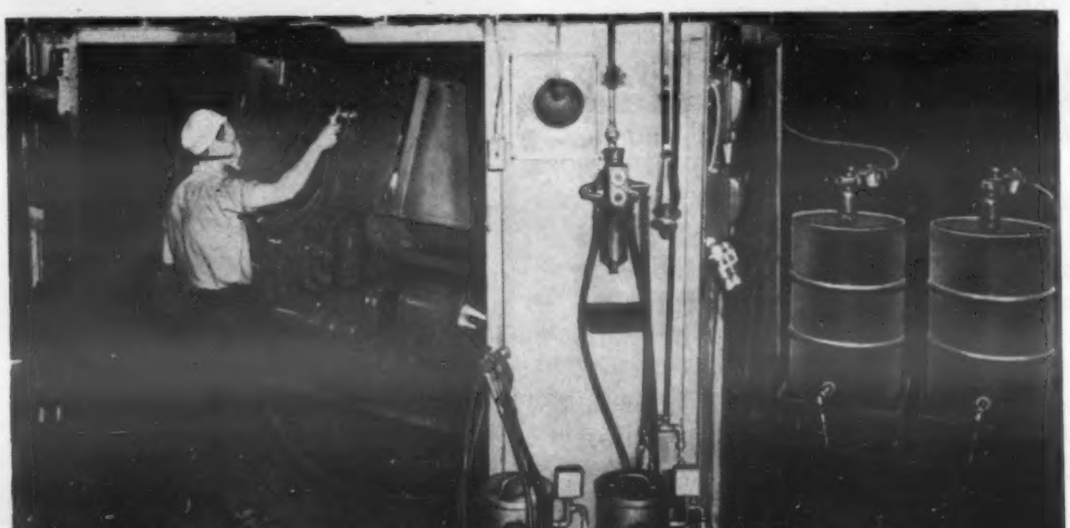
Cast iron quenching dies used in heat treating steel propeller blades.



Heat treated cams provided a long wearing, hard surface of 375 Brinell.

Time, Labor and Materials Saved by Hot Spraying Industrial Organic Finishes

by LEON M. JAROFF, Assistant Editor, Materials & Methods



Using the hot spray process, this worker can apply organic finishes in half the time required by cold spraying. (All illustrations Courtesy Bede Products, Inc.)

• ONE OF THE most important developments in the finishing field in recent years has been the successful hot spray application of lacquers and, more recently, synthetic enamels, to an ever increasing number of industrial products.

Essentially, the hot spray process involves a system of organic finish formulation and application which depends upon the effect of heat rather than the addition of thinner to reduce the finish to spraying viscosity. By heating a highly concentrated lacquer or synthetic enamel to 160 F, for example, and spraying at that temperature, it is possible to apply (at normal spraying viscosity) a finish containing 50 to 60% more film forming ingredients than possessed by those formulated for spraying at room temperature.

Although considerable interest was generated by the introduction of hot spraying in the late thirties, most of the early industrial tests were prematurely conducted with insufficient technical developments to produce the required finishes. Consequently, erratic performance and unsatisfactory results caused hot spraying techniques to be generally discarded in this country. But there were many who realized that the theory behind the process was sound and that many benefits could be realized if the mechanics of hot spraying were perfected. Spurred on by reports of successful applications in Europe, research continued both before and during World War II, eventually effecting improvements which resulted in the revival of the hot spray process in the post-war period.

Materials-Saving Qualities

Today, with growing shortages of solvents, thinners and other organic finish ingredients causing concern in industry, the inherent materials-saving qualities of hot spraying are assuming even greater importance. One of these, a saving in volatiles, results from the fact that organic finishes sprayed at elevated temperatures contain a much higher ratio of non-volatiles to volatiles. This higher solids content reduces the volume of volatiles necessary to apply any given thickness of film by approximately 40%, in most cases. So that good flow can be obtained, it is necessary to use richer, higher-boiling solvent mixtures which cost more per gallon than the mixtures used in conventional finishes. Nevertheless, the saving in the amount of volatiles required to apply any given quantity of film-forming ingredients at hot spray temperatures more than offsets their higher cost per gallon and, in fact, effects a 15 to 25% reduction in cost.

Another significant saving is in the amount of material, both volatile and non-volatile, that is normally lost in overspray. With cold spraying it is estimated that 50% of the organic finish is often lost in overspray and that, even under ideal conditions, at least 25% is wasted. Several factors combine in the hot spray process to reduce this loss considerably. Because organic finishes applied at elevated temperatures reach the surface being sprayed at a higher viscosity than those applied at room temperatures, coatings at least twice as thick can be formed without encountering any danger of sagging. These thicker coats and the higher solids content of the organic finish substantially reduce the number of coats required to apply a given thickness of film and increase the coverage per gallon. This, in turn, means fewer passes, shorter time of application, and less waste motion—all resulting in less material lost in overspray. In addition, the lower atomizing air pressures used in the hot spray process result in a 5 to 15% reduction of spray dust, in which form considerable material is wasted during cold spraying.

Lower Labor Costs

Another economical aspect of the hot spray process—lower labor costs—follows directly from the reduction in the number of passes required to attain a finish of given thickness. It is estimated that a sprayer who requires ten strokes to properly cover a given surface by cold spraying can achieve equal quality with only six or seven strokes using the hot spray process. In many plants using hot spray lacquer, additional labor costs for reworking rejects caused by blushing, sagging and orange peel have been greatly decreased. In fact, blushing, a condition in which the lacquer assumes a white, milky appearance, is largely eliminated in hot spraying

because lacquer applied at elevated temperatures does not usually cool much below atmospheric temperature during drying. In cold spraying, however, the rapid evaporation of the solvent cools the lacquer film enough to sometimes cause condensation of moisture from the air. This moisture throws the lacquer out of solution, imparting to it the aforementioned milky appearance.

Sagging also is greatly reduced by hot spraying because of the greater viscosity of the finish upon reaching the surface being sprayed and faster solvent release—both of which are brought about by higher temperatures of application.

The third cause of frequent rejects in cold spraying processes, orange peel, a condition in which the surface of the finish resembles the pitted skin of an orange, is substantially decreased in the hot spray process because the higher temperature of the freshly laid finish allows improved flow-out. Furthermore, improper atomization, often the cause of orange peel, is far less common in hot spraying than in cold.

Also contributing to the number of rejects encountered in cold spraying is the wide range of spraying temperatures, which results in erratic performance and non-uniform results. In the hot spray process, however, uniform temperature at the spray gun is always maintained, even if a new drum of lacquer or enamel is brought in from outside during extremely warm or cold weather. (See Fig 1).

Comparative Tests—Lacquer

A summary of a test performed by the Commercial Solvents Corp. to demonstrate the economies gained by the application of high-solids lacquers at elevated temperatures is presented in the accompanying table. For this test, two light green automotive alkyd resin lacquers were prepared, one for spraying at room temperature and the other for application at 155 F. The composition of the solids was identical in the two lacquers, the difference being in the ratios of volatiles to solids at spraying viscosity and in the composition of the volatile portion. The lacquers were sprayed on 20-gage fender stock steel panels coated with a baked automotive primer and surfacer.

Using room temperature spraying, two coats were applied one-half minute apart, followed after 5 min by two additional coats ½ min apart. With the lacquer sprayed at 155 F, however, only two coats were applied, ½ min apart. After thorough drying, the panels were sanded with a special reciprocating abrasion instrument to determine relative orange peel. The number of strokes required to remove all traces of orange peel with this instrument is shown in the table.

From the table, it can be seen that the lacquer applied at 155 F contained more than 50% more solids than the lacquer applied at room temperature. Also, by spraying somewhat heavier coats, the same thickness of film was applied in two coats by hot spraying as was secured with four coats of conventional lacquer at room temperature. Furthermore by moderately increasing the liquid and air pressures, the two coats of lacquer were hot sprayed in approximately half the spraying time (and with half the labor) required for four coats of ordinary lacquer. This means, in effect, that the capacity of a finishing plant is increased when hot spraying is employed. Reduction in the number of coats from three to two is equivalent to adding 33% extra capacity (which would mean one-third more floor space, guns, operators, and compressor capacity). Similarly, reduction of a two-coat finishing schedule to a one-coat, which frequently becomes possible, is equivalent to adding 50% to the existing finishing capacity.

Although the cost of volatiles per gallon was appreciably higher for the lacquer sprayed at 155 F, there was a saving of about 22% in the cost of volatiles required to apply a pound of non-volatiles. The flow of lacquer applied at 155 F was slightly better than that of the one sprayed at room temperature, as is indicated by the fact that 15% less sanding was required to remove all traces of orange peel.

Comparative Tests—Enamel

Hot spraying of synthetic enamel has also met with considerable success. Bede Products, Inc., whose hot spray equipment is used industrially for spraying synthetic enamels, has conducted many comparative tests with hot and cold spray techniques.

An analysis of a typical test gave the following results:

	Cold Spray	Hot Spray
Enamel as mixed:		
Solvent:	48 lb	40 lb
Solids:	66 lb	66 lb
Volume:	12 gal	11 gal
Viscosity:	26 sec	48 sec
Air pressure:	70 psi	50 psi
Liquid pressure:	16 psi	11 psi
Temperature of material entering spray gun:	68 F	180 F
Viscosity of material entering spray gun:	26 sec	18 sec

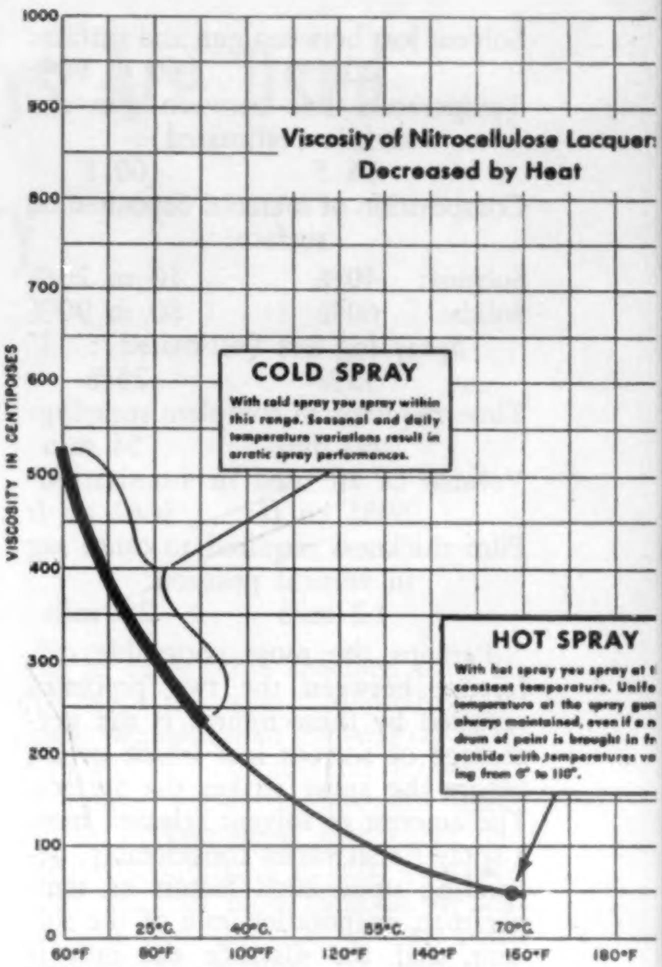


Fig. 1—Viscosity of lacquers is decreased by heat, as shown by this chart.

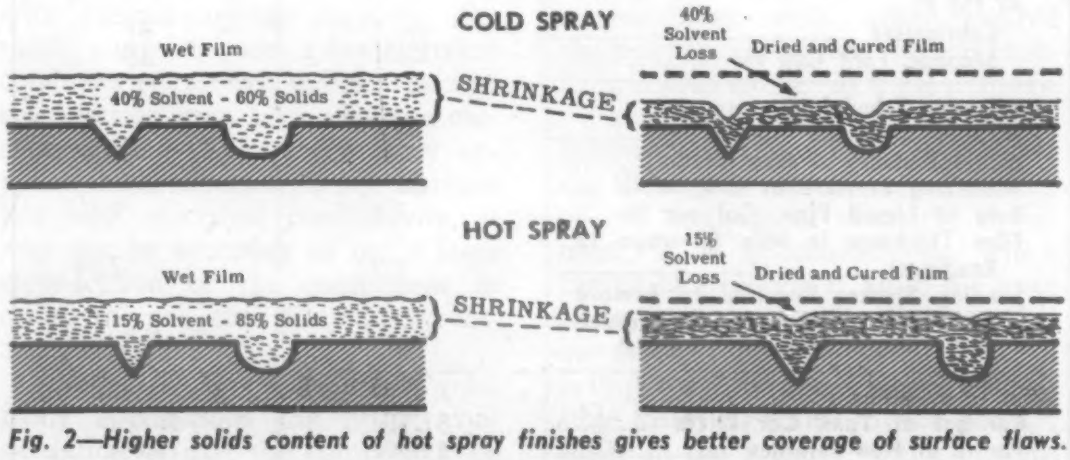


Fig. 2—Higher solids content of hot spray finishes gives better coverage of surface flaws.

Solvent loss between gun and surface:
20% 60 to 80%

Temperature loss between gun and surface (estimated):
14 F 60 F

Composition of material deposited on surface:

Solvent: 40% 10 to 20%

Solids: 60% 80 to 90%

Spray fog loss (estimated):
35% 25%

Time required to complete spraying:
60 min 54 min

Volume of air used in atomization:
6981 cu ft 3682 cu ft

Film thickness required to cause sag in vertical position:
1.2 mils 2.6 mils

Perhaps the most noticeable difference between the two processes revealed by these figures is the percentage of solvent loss which occurs before the spray strikes the surface. The amount of solvent released from a spray finish varies considerably, depending upon such factors as temperature, evaporation rate of the solvent, and the distance the gun is held from the surface. But it generally averages between 16 and 22% for room temperature spraying. Therefore, the coat of finish deposited on the surface has a greater proportion of solids and a lower solvent content than the original material.

In the hot spraying of both lacquers and synthetic enamels, however, the solvent loss is much greater—sometimes as much as 80%—because the spray leaves the gun at temperature close to the boiling point of the solvent. This solvent loss is very desirable, and brings about many of the benefits gained by hot spraying. Nevertheless, it is probably the most crucial factor in hot spraying, because, if the remaining solvent is not sufficient to allow proper flow, the process fails.

Also of interest in the above statistics is the fact that the amount of pressurized air required for atomization is reduced nearly in half with the hot spray process. Over an entire year, this can amount to an appreciable saving.

Physical Properties

Differences in physical properties of organic finishes applied by hot or cold spraying are negligible, except in the case of shrinkage. It has often been observed that the ability of a finish to fill surface imperfections is inversely proportional to the solvent content of the wet film applied to the surface. Surface imperfections are revealed through the cured film because of the evaporation of the solvent and consequent shrinkage in the film. Because the hot spray process deposits a film on the surface with greatly reduced solvent content, shrinkage is reduced and filling properties proportionately improved. (See Fig 2)

Otherwise, such properties as drying time, hardness, sandability, print resistance, and cold-check resistance do not vary appreciably in cold or hot spray finishes of the same thickness and solids formulation. When heating a lacquer results in decreasing its viscosity below that of normal spraying range, however, nitrocellulose of a higher viscosity type or a larger proportion of nitrocellulose can be used in formulation—resulting in finishes with improved cold-check resistance, toughness, flexibility and print resistance. This is done, of course, only at a sacrifice of some of the savings in labor and material mentioned earlier.

Briefly summarizing the comparison of hot and cold spray processes, nine important advantages of hot spray stand out:

1. Solids are higher and the thickness obtained for each pass is greater.
2. Solvent waste is lower.
3. Coverage per gallon is increased.
4. Fewer coats are needed.
5. Capacity of the finishing plant can be increased.
6. The finish has better flow-out (less orange peel).
7. The finish has less tendency to sag.
8. Blushing is eliminated in lacquers.
9. Toughness and cold-check resistance of lacquers can be increased.

With practical organic finish heaters now on the market, continuing progress in the formulation of new finishes, and a marked lessening of the skepticism about hot spraying which was so prevalent a few years ago, the hot spray process has passed through its trial and error stage and emerged as an outstanding finishing development of the decade.

Savings Obtained by Hot Spraying

Composition of the Lacquers	Lacquer for Application at: Room Temperature	155 F
Non-Volatiles, lb per gal ¼ Sec		
Nitrocellulose (Dry Basis)	0.56	0.85
Alkyd Resin A	0.56	0.85
Dibutyl Phthalate	0.22	0.34
Pigment	0.51	0.76
Solids Content, lb per gal	1.85	2.80
Volatiles, % by volume n-Butyl Acetate	25	40
Butanol	10	15
Ethyl Acetate	10	—
Ethyl Alcohol*	5	10
Toluol	25	—
Naphtha (203 to 266 F)	25	—
Xylol	—	17.5
Naphtha (257 to 293 F)	—	17.5
Viscosity of the Lacquers		
At Room Temperature:		
Centipoises	37	170
Seconds, Ford Cup No. 4	19	47
At 155 F:		
Centipoises	—	37
Seconds, Ford Cup No. 4	—	19
Application Schedule		
Number of Coats Applied	4	2
Liquid Pressure at Gun, in lb	6	9
Atomizing Pressure at Gun, in lb	60	65
Rate of Liquid Flow, Gal per Hr	7.1	9.4
Film Thickness in Mils (Average 12 Readings)	2.92	2.96
Sanding Strokes Required to Remove All Traces of Orange Peel (Average of 5 Tests on Each of 3 Panels)	30	25
Cost of Volatiles		
Per gal at Tank Car Prices	31.79c	38.03c
Per lb of Non-Volatiles	13.90c	10.83c

** Including ethyl alcohol ordinarily added with the nitrocellulose.*

Acknowledgment

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How Copper-Base Casting Alloys Are Used in Electrical Industry

by R. A. COLTON, Research Dept., American Smelting and Refining Co.

Manufacturing cost of electrical equipment can be frequently cut by proper selection of materials, based on conductivity, strength, corrosion resistance, machinability and castability.

• IN WORKING WITH designers, engineers and production men in the electrical equipment industry, it has been found that the knowledge of alloys available for use is generally incomplete. For this reason much equipment today is over-designed, with larger and heavier components than might be needed if alternate alloys were used. Also, there has been a tendency to use only the more conventional alloys, many of the newer developments apparently being unknown to engineers in the electrical industry. It is the purpose of this article, therefore, to consider the requirements of electrical equipment and to describe the materials available for use in the industry. Only copper-base alloys will be covered since they are best suited to the peculiar requirements of the electrical industry.

Materials Requirements

The electrical industry manufactures sub-station equipment, pole line hardware, hot-line connectors and switchgear. Such equipment requires a considerable variety of materials with a wide range of properties; no other field of manufacturing demands the same set of properties as that needed in electrical equipment.

When the designer or the engineer building electrical equipment has specific requirements with regard to strength, conductivity, machinability and cost, it is worthwhile to consult with the metallurgist of the ingot producer or of the foundry to obtain the best material for the job. Usually it is possible to alter compositions to produce specific properties within the limitations discussed below. A wide variety of alloys can be produced and a number of combinations of desirable properties can be obtained by careful blending of the various alloy ingredients.

The most important properties and characteristics involved in proper alloy selection will be discussed briefly below:

Electrical Conductivity—Obviously, electrical conductivity is an important requirement for alloys used in much of the equipment for this industry. In many applications, because of other considerations, the conductivity is not important. But where current carrying is a part of the designed performance of a component, high electrical conductivity is naturally desirable. When the highest counductivity is needed, of course, pure copper is normally specified. It is not this type of application that offers difficulty to the designer, but rather a combination of conductivity and some other special property.

Conductivity is often confused with current-carrying capacity. Actually, a material with a low electrical conductivity cast in a sufficiently large cross-section may have adequate current-carrying capacity for many applications. Conversely, if the material has high electrical conductivity, it may not be necessary to use a large cross-section of the component in order to get the desired current-carrying capacity.

Mechanical Strength—In a great many applications the prime consideration is that the component be able to carry some specified load. If this were the sole consideration, it might be possible to use steel or other materials at a considerable economic advantage. However, strength must usually be combined with other desired characteristics so that procurement becomes more difficult. When strength and conductivity are both needed, the number of materials which can be selected for any given application is correspondingly limited.

Corrosion Resistance—Since large quantities of electrical equipment must operate outdoors, it is necessary to provide adequate resistance to atmospheric corrosion in the manufactured components. Many copper-base alloys have excellent corrosion resistance, but combining this property with other desirable properties is sometimes a major problem. Some parts of the industry have particularly stringent requirements as to the nature of the materials they can use because of the danger of stress corrosion or corrosion cracking.

Machinability—The ability to be machined readily is a materials requirement in most industries, and the electrical industry is no exception. When components are manufactured in extremely large quantities, good machinability is desirable to reduce finishing cost to a minimum. However, the difficulty of combining good machinability with other desired characteristics sometimes creates problems unique to the electrical industry.

Foundry Characteristics—While the behavior of any particular alloy in the foundry is not the direct concern of the designer of electrical equipment, it is a consideration which cannot be overlooked. Since the price of any component depends somewhat on the difficulty of manufacture, it is important to specify whenever possible materials which can be handled easily in the foundry. Unfortunately,

certain other requirements listed above are not compatible with ease of casting, and meeting them poses serious problems in the fabrication of certain alloys.

High-Conductivity Alloys

Ideally, the highest possible electrical conductivity for manufacturing purposes would be found in castings made of high-purity copper; theoretically, conductivity would be in excess of 100%. Castings rarely have theoretical properties, however, and practical conductivity would be somewhere between 95 and 100%; this is because of the difficulty of making sound, acceptable castings of copper alone, and also because of the great difficulty experienced in machining copper castings. The principal problem is that the castings are usually porous, containing many large blowholes, and may be unacceptable to the user. Porosity or other defects in the casting tend to reduce the effective conductivity of the section by decreasing the amount of material available for carrying current.

Copper when cast without any alloy additions also has poor structural properties. Copper itself is soft, with low tensile and yield strengths, and has little load-carrying capacity. For that reason it is often desirable to increase the strength properties of copper while retaining as much of the conductivity as possible.

It is usually essential that some element be added to the copper in processing to help control porosity. In selecting this extra element several considerations must be kept in mind. In the first place, the purpose of the element is to deoxidize copper or to remove the oxygen in the molten metal so that it cannot contribute to porosity in the casting. Also, the additional alloy element must have a minimum effect on the electrical conductivity while acting as a deoxidizer. It is usually desirable that this extra element have some strengthening effect on copper and improve the machinability at the same time.

The effects of a number of second elements on the conductivity of copper are shown in Fig 1. It can be seen that only extremely small amounts of most elements are permissible if the conductivity of the material is to remain substantially high. For practical purposes, copper castings having 85% or better electrical conductivity are usually considered to be high-conductivity castings. In order to maintain this value it is necessary to limit the amount of the second element addition, as indicated in Fig 1.

The most common additions to copper for control of porosity in castings and to retain high conductivity are: zinc, which can be used in amounts up to 2%; lithium, which has a strong effect on the conductivity but is an excellent deoxidizer and helpful in making castings; boron, added as calcium boride, which is also a valuable deoxidizer; phosphorus, which must be controlled carefully so that it does not reduce the conductivity; and tin, which makes the metal more castable but has a rather marked effect on the conductivity. Other elements can be used for this purpose but those listed above are the principal alloy additions in copper used for conductivity purposes. Different degrees of difficulty are experienced in using these various elements, and experience and close foundry control are required to obtain sound castings with high electrical conductivity.

The strength of copper is increased

Table I—Properties of Copper-Base Alloys Used in Electrical Industry

Alloy	Nominal Composition: Cu	Sn	Pb	Zn	Al	Be	Others	Ten Str, Psi	Yld Str, Psi	Elong; % in 2 In.	Brinell Hardness	Elect Cond, % Cu
High Strength Bronzes												
Herculoy Electrical Bronze	89	1	—	5	—	—	5 Si	65,000	30,000	30.0	—	—
High Strength Aluminum Bronze	81	—	—	—	11	—	4 Fe 4 Ni	90,000 112,000*	40,000 70,000*	10 5*	—	—
Aluminum Bronze	86	—	—	—	10	—	4 Fe	75,000 100,000*	30,000 40,000*	20 12*	—	—
Aluminum Bronze	89	—	—	—	10	—	1 Fe	72,000 90,000*	25,000 40,000*	25 15*	—	—
General Purpose Alloys												
85-5-5-5	85	5	5	5	—	—	—	35,000	17,000	30	60	15
83-4-6-7	83	4	6	7	—	—	—	33,000	15,000	25	55	16
Regular Herculoy	89	1	—	5	—	—	5 Si	50,000	20,000	50	90	6
Everdur	95	—	—	—	—	—	4 Si 1 Mn	50,000	15,000	50	75	6
Navy "M"	88	6	1.5	4.5	—	—	—	38,000	17,000	35	65	14
High Strength—High Conductivity Alloys												
Chromium Copper	99.5	—	—	—	—	—	0.5 Cr	50,000	25,000	20	—	85
Beryllium Copper	97.5	—	—	—	—	2.0	0.5 Co	160,000	140,000	2	—	25
Beryllium Copper	98.2	—	—	—	—	0.3	1.5 Ni	75,000	45,000	5.0	—	55
Beryllium Copper	95.0	—	—	—	—	1.0	2.0 Co 2.0 Ni	95,000	45,000	10	—	50
Moderate Strength—Moderate Conductivity Alloys												
	97	1	1	1	—	—	—	20,000-33,000	10,000-14,000	25-50	—	25-40
	96	1	1	2	—	—	—					
	95	1	2	2	—	—	—					
	94	2	2	2	—	—	—					
	94.5	1.5	1	3	—	—	—					
	94.5	—	0.5	4.5	—	—	—	32,000	13,000	45	—	52
	97	—	—	3	—	—	—	23,000	10,000	55	—	65

** Properties obtained by suitable heat treatment of castings.*

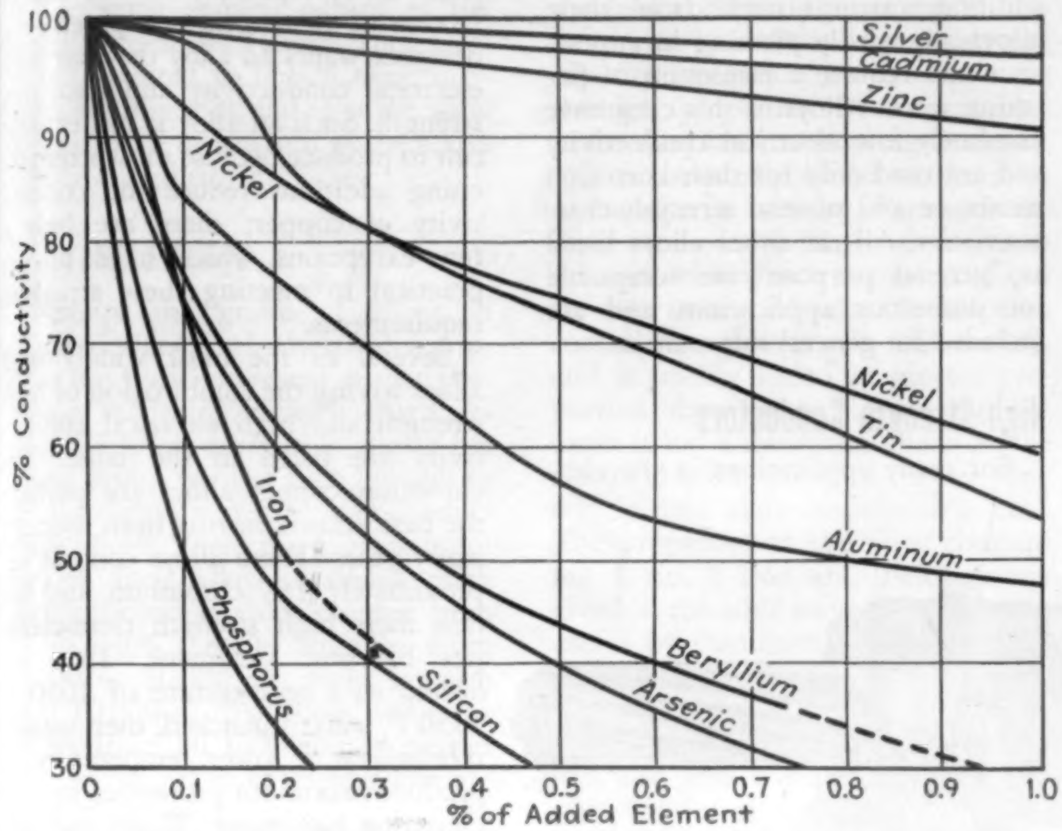


Fig. 1—This graph illustrates the effect of welded elements on the conductivity of cast copper.

by alloy elements dissolved in the copper but only small quantities of certain of these elements can be permitted if high conductivity is to be maintained. For this reason most of these elements actually have a minimum effect on strength, and copper with 85% conductivity or better that is cast without porosity usually has physical properties only slightly better than pure copper.

High-Strength Alloys

In Table I are listed the properties of the two groups of copper-base alloys usually considered most suitable for high-strength application in the electrical industry. Aluminum bronzes are alloys of copper, aluminum, iron and, possibly, manganese. They have excellent physical properties, the tensile strength running as high as 120,000 psi. To achieve the highest properties in these alloys it is necessary to heat treat them. The as-cast properties, however, are quite good and usually suitable for most applications. There are a number of these alloys available, as shown in Table I, and selection depends on the particular combination of strength properties desired. In addition to having high strength, these alloys are also corrosion resistant. Machinability is normally poor, and foundry characteristics are not too good. It requires experience and specialized techniques to make sound, acceptable castings from the aluminum bronzes.

The other group of alloys that can be used satisfactorily for high-strength purposes is the silicon bronzes, represented here by Herculoy Electrical Bronze. These alloys have high as-cast properties as shown. In addition, they are excellent alloys in the foundry and have good machinability. They are widely used at the present time for a variety of electrical castings, including pole line hardware, connectors, and the like.

Corrosion Resistant Alloys

In general, all of the alloys of copper listed in this article have good resistance to the atmosphere. The aluminum and silicon bronzes and pure copper probably have the best corrosion resistance of all the materials listed, but all of the other alloys discussed here will usually perform acceptably.

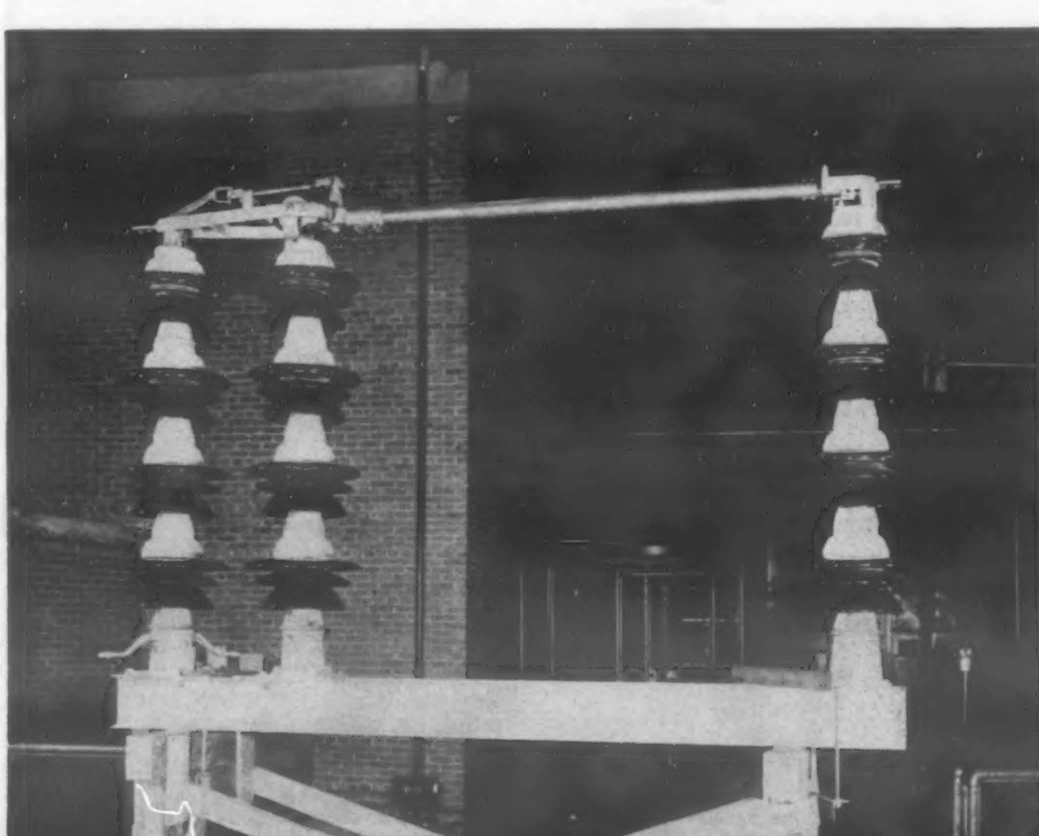
General Purpose Alloys

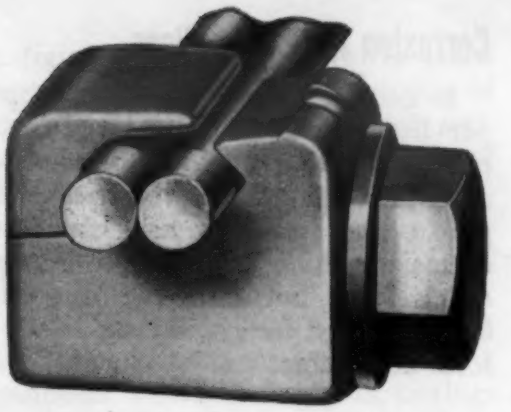
Table I also gives the mechanical and electrical properties of copper-base alloys used for structural components where current-carrying capacity is not of prime importance. These alloys have average strength properties and fairly low conductivity.

Outstanding example of alloys of this type is the 85-5-5-5 copper-tin-lead-zinc alloy which is used widely throughout the electrical industry. It combines moderate strength, castability in the foundry and excellent machinability, with acceptable corrosion resistance. This alloy is also used widely in other industries.

Another group of general purpose alloys which has found its place in the electrical industry is the silicon bronzes of the Herculoy and Everdur type. These alloys offer good strength properties with extremely high corrosion resistance, fair machinability, and good foundry characteristics. In

Copper-base casting alloys find wide application in sub-station equipment. (Courtesy Electrical Engineers Equipment Co.)





This unit connector is made from Everdur Silicon Bronze with wrought bronze bolts and washer. (Courtesy Fargo Mfg. Co., Inc.)

addition, castings made from these alloys are usually pleasing in appearance and require a minimum of finishing work. Alloys of this class have extremely low electrical conductivity and are used only for their corrosion resistance and general strength characteristics. All the other alloys listed as "general purpose" are acceptable for numerous applications and are included for general information.

High-Strength Conductors

For many applications in the electrical field, especially in the manufacture of switchgear equipment, the designer wants an alloy that has high electrical conductivity and also high strength. Such an alloy is rather difficult to produce because most strengthening additions reduce the conductivity of copper; there are only a few exceptions which have proven practical in meeting these stringent requirements.

Several of the most widely used alloys having the combination of high strength and high electrical conductivity are listed in the table. The chromium-copper alloys are perhaps the best known, having been used for many years. These alloys contain approximately 1% chromium and obtain their high strength characteristics by heat treatment. They are heated to a temperature of 1650 to 1850 F, water quenched, then usually reheated at a lower temperature to produce maximum properties by precipitation hardening. When the precipitate comes out of solution and thereby strengthens the alloy, it leaves the matrix metal essentially copper, which provides high conductivity.

Another group of alloys offering high strength and high conductivity is that of the beryllium-copper types. These are commonly alloys of copper containing 1% beryllium, with cobalt and silicon also present. These alloys also obtain their high physical properties by precipitation hardening, as described above. The properties of these alloys are listed in the table, and it can be seen that it is possible to obtain exceptional strength with high conductivity.

A group of high strength-high conductivity alloys frequently used in electrical equipment is copper with about 1% cadmium. These alloys have high conductivity in the as-cast condition but realize their high strength only in the wrought condition. They are work-hardenable alloys, and as such are not properly listed with cast materials.

Both the copper-chromium and beryllium-copper alloys are difficult to manufacture in the foundry and offer considerable difficulty in machining. Because of the difficulty in manufacture and because of the cost of the ingredients, both of these groups of alloys are fairly expensive and are used only when their unique properties can be justified economically.

There are other alloys of the heat-treatable type available for use in the electrical industry. Most of these are patented compositions which cannot be made except by licensees, and are

In this spacer type connector, Everdur Silicon Bronze is used for the connector, high conductivity copper for the spacer bar, and aluminum bronze for washers and bolts. (Courtesy Fargo Mfg. Co., Inc.)

The shell of this service cable dead end is cast of Herculoy Electrical Bronze. Exposed parts are either silicon or aluminum bronze except for the cable, which is made from phosphor bronze wire. (Courtesy Fargo Mfg. Co., Inc.)

This automotive type messenger dead end consists of an aluminum bronze casting with auxiliary parts of wrought aluminum and phosphor bronzes. (Courtesy Fargo Mfg. Co., Inc.)

of the same general nature as the two alloys described above. They must be heat treated to obtain their high physical properties, and offer the same difficulties in production as the alloys already described.

Compromise Alloys

Perhaps the group of alloys in which designers of electrical equipment are most interested is that possessing moderate strength characteristics with conductivities above the lowest group but not high enough to be considered with the high-conductivity alloys. There are a great number of such alloys available with electrical conductivities ranging from 25 to 50%, tensile strength from 20,000 to 30,000 psi, yield strength from 10,000 to 15,000 psi, and elongation from 20 to 50%. Properties of a typical group of these alloys are listed in the table.

The production of alloys of this type for the electrical trade depends on knowledge of the effects of the various alloying elements on the conductivity of pure copper. What is desired normally is to add enough alloy elements to increase the strength characteristics and improve the foundry characteristics of the alloy, but still retain enough electrical conductivity so that section sizes can be reduced to economical limits. Unfortunately, there are no standard alloys of this type since a great many compositions are possible and have been specified by designers in the electrical manufacturing industry. Most of these alloys contain small amounts of tin, lead and zinc in varying quantities. The properties of the various combinations are usually quite similar.

The addition of tin to copper strengthens it greatly and, at the same time, reduces the electrical conductivity markedly. Therefore, it is necessary to limit the amount of tin present if the conductivity is to be kept acceptably high. For practical purposes tin content is usually restricted to 1 or 2%. This has quite a beneficial effect on the strength properties and does not reduce the conductivity too severely.

Lead is frequently added to this alloy for machinability purposes. The presence of lead does not detract from the electrical conductivity except that 1% of lead replaces 1% of copper so that any cross-section has less copper available to carry current. Lead is not dissolved in the copper but is present as discrete particles and improves the machinability by breaking up continuity of the matrix. Usually the lead content is restricted to 1% so as not to reduce current-carrying capacity too greatly or to reduce the strength properties. Too much lead in the alloy has a weakening tendency.

Zinc is usually added to the alloy to enhance its foundry characteristics. Zinc is a deoxidizer and increases the ease with which the material can be cast in the foundry. It helps to control the porosity in the casting, and is usually added in greater proportion than either tin or lead because it has a minimum effect on the electrical conductivity of copper. One widely used alloy contains 2% zinc. The properties of the alloy containing 1 tin, 1 lead and 2% zinc are given in the table and are found quite useful by manufacturers in the electrical trades.

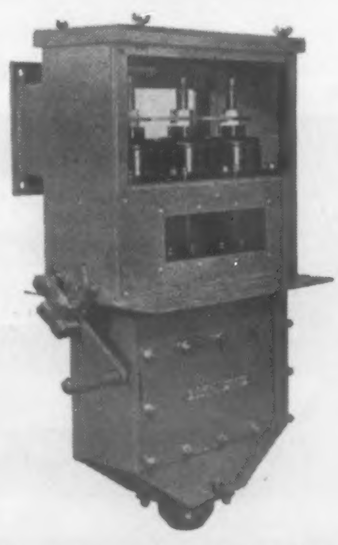
It is possible to make other combinations of tin, lead and zinc which will also give useful properties. The manufacture of such alloys must be carefully controlled, however, so that other contaminating elements are not present. Small amounts of iron which may be picked up in manufacture can seriously decrease the electrical conductivity of such an alloy. Contamination by silicon and aluminum is highly undesirable and must also be avoided. Obviously such an alloy must be made only from high grade materials and with great care. For that reason, foundries usually do not try to make such alloys themselves but buy them already mixed from an ingot producer.

Another class of alloy in which electrical conductivity, strength characteristics and machinability are all moderately good are those containing copper, lead and zinc. Since zinc has a minimum effect on the electrical conductivity of bronzes, it is possible to add larger quantities of it than of almost any other useful element. One widely used alloy of this type contains 4.5 zinc, 0.5% lead and the balance copper. The electrical conductivity of this alloy will always run in excess of 50%, although tensile strength will always be below 35,000 psi. This alloy is fairly easy to handle in the foundry because of the large amount of zinc present. The presence of 0.5% lead makes it more machinable and does not detract greatly from its electrical conductivity. It is possible to reduce the zinc content of an alloy of this type and improve the electrical conductivity. As the zinc content is reduced, strength properties also decline and ability to make good castings is reduced at the same time.

It should be apparent that in selecting an alloy for use in electrical equipment, there is economic advantage in getting maximum conductivity with maximum strength. If good strength properties can be obtained with good conductivity, the amount of metal needed for the component can be minimized. Since strength and conductivity are usually opposed, all the alloys produced up to this time have been compromises and the designer seldom has an entirely suitable material at his disposal.

Machinable Alloys

Since the ability to machine castings with ease is desired in almost all manufacturing processes using castings as raw materials, it should be pointed out that there are a number of elements which can be added to copper that will improve its machinability. In the first place, whenever copper is hardened by the addition of tin, zinc, silicon, aluminum, etc., its machinability improves. On the other hand, some of these elements have deleterious effects on the conductivity and cannot safely be present in the copper if high conductivity is desired. For that reason it has been necessary to limit the additions to copper to those elements which have minimum effects on conductivity and maximum effect on machinability. Lead is such an element. Lead, when present in copper in small amounts, greatly improves machinability with little effect on the conductivity. Other elements will accomplish the same end, but most of them are more expensive and some of the compositions are patented. Among such elements are selenium and tellurium. Neither of these elements aids in the manufacture of sound castings, but both do improve the machinability of copper.



This high voltage device makes good use of copper-base casting alloys.

Materials at Work

Here is materials engineering in action . . .
New materials in their intended uses . . .
Older, basic materials in new applications . . .

BRONZE EXTRUSIONS ***These architectural bronze extruded sections were specified for elevator and rudder counterweights on Boeing's new B-47B Stratojet bomber (shown above) instead of the more commonly-used steel counterweights whose magnetic properties would have adversely affected the plane's fluxgate compass. The Revere Bronze Alloy 283 extrusions effected so great a saving in machining costs that they are now being used for counterweights even where magnetic properties are not a factor in the selection of materials.***

MOISTURE-RESISTANT FILM *In less than 30 min, this winch aboard a U. S. Navy aircraft carrier was stripped, lubricated, and ready for service after being sealed in Vinylite resin-based film for 4½ years. The tough, non-flammable film, resistant to oil, grease, rot, mildew, fungi and most chemicals, is used to seal many pieces of dock equipment in the Navy's "mothball fleet" from the elements. In this typical ship-reactivating operation, the coating was slit with a knife and stripped off in a few minutes. With the aid of moisture-absorbing silica gel, the film covering had preserved the winch so that it required only lubrication before being put back into service.*

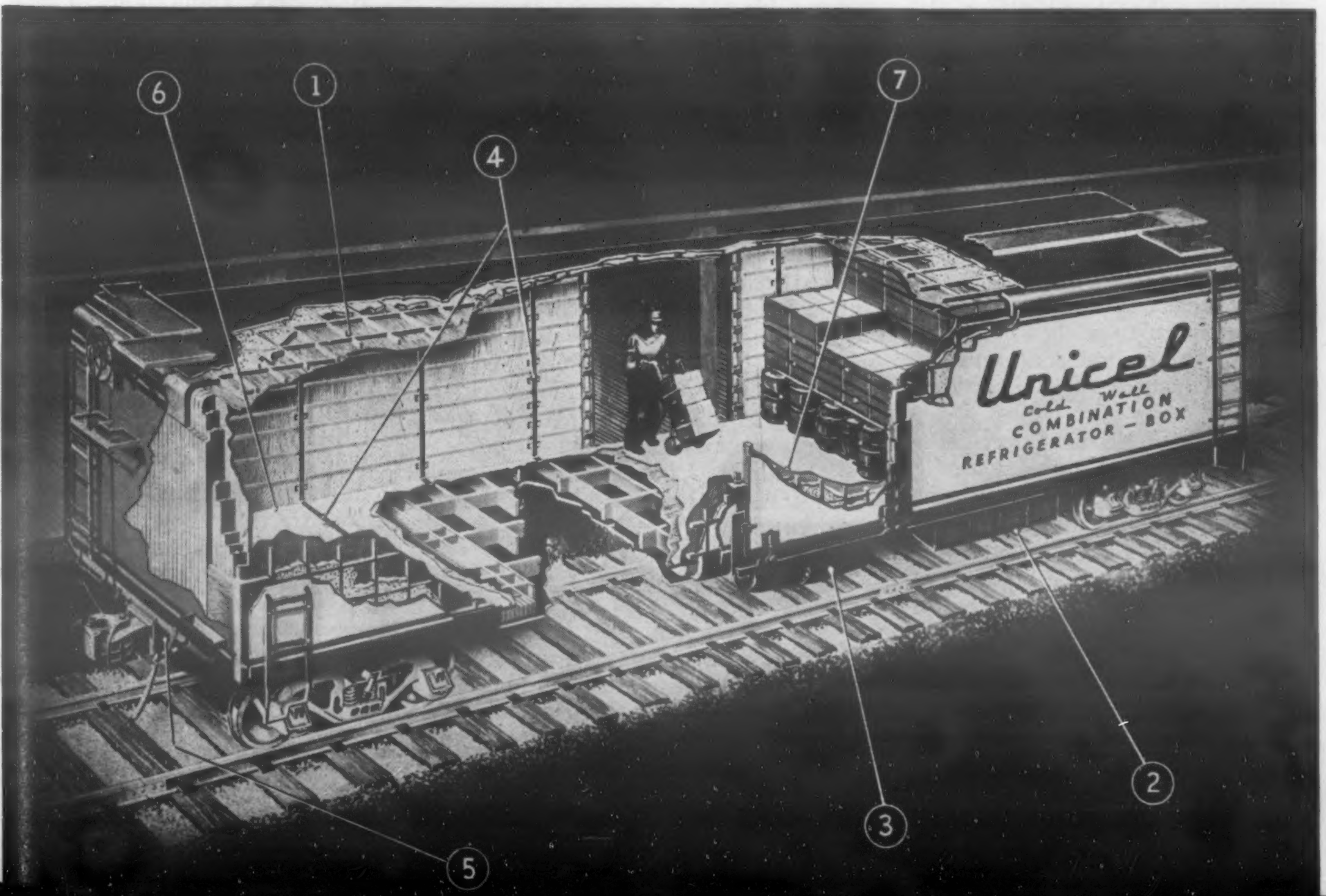
PLYWOOD RAILROAD CAR *This cutaway drawing demonstrates the features of the revolutionary new Unicel combination freight-refrigerator car produced by the Pressed Steel Car Co., Inc. Some of its unusual advantages include:*

CONSTRUCTION: The car is made of cellular laminated super-strength plywood (1) molded and pressed into a single unit structure that is stronger than a conventional car made of steel. Frigidaire mechanical refrigerating unit (2) is powered by Diesel fuel enroute (3), and by electricity at sidings and warehouses.

DAMAGE-REDUCING FEATURES: New, specially-developed Uni-strapping braces and fastens Unicel's lading more securely to permanent, built-in tie-downs (4). Less shifting prevents damage. The Unisorb Floating Draft Sill (5) has an important shock-absorbing and damage-reducing function. A rubber sleeve mounted to the car's end-couplers cushions and absorbs road shocks.

SANITARY FEATURES: Hinged steel floor racks make cleaning easier. Sanitary interior with rounded (6) corners and smooth, flush interior door and floor construction (7) cannot pick up dirt as easily and can be washed down faster.

ECONOMICAL FEATURES: Approximately 11 tons of vitally-needed steel per car are saved by the plywood construction, making the car lighter to pull when empty. Nevertheless, it carries a bigger payload when full. The actual cost of Unicel cars is less than that of steel freight cars and is expected to be further reduced.



Industrial Applications of Thermosetting Laminated Plastic Tubing

by DUANE E. ROLAND, Superintendent, Synthane Corp.

At least ten grades of thermosetting laminates are available, providing a wide range of mechanical, electrical and corrosion resistant properties.

• THERE ARE few phases of industrial activity in which some form of tubing has not long been either a product or manufacturing tool. Many tubing materials—metal, ceramic, glass, rubber and wood—have been and will always be specified wherever one physical characteristic is predominant. Thermosetting laminated plastics are often specified by design engineers where industrial tubing applications require a combination of electrical, chemical and mechanical characteristics.

Thermosetting laminates are produced by applying heat and pressure to multiple layers of a paper or fabric —called the filler—that are impregnated with a thermosetting synthetic resin—called the binder. During the laminating process, pressures from 1000 to 2500 psi are applied at temperatures from 270 to 340F, depending upon the filler and binder used.

Laminated plastic tubing is produced by two major techniques—rolled-molded and rolled. Rolled tubes are cured by the application of heat alone; molded tubes are cured under heat and pressure in molds. Both techniques take place after the resin-impregnated filler material has been wound to a specified number of layers on a mandrel conforming to the inside diameter of each particular tube size.

A variety of electrical, mechanical and chemical characteristics are included in the ten grades (classified by NEMA) of laminates which cover the requirements of most industrial tubing. Special filler and binder combinations are used for those applications not covered by these grades. The NEMA grades now being used in laminated plastic tubing are:

1. Paper base—Grades X, XX, XXX
2. Fabric base—Grades C, CE, L, LE
3. Asbestos base—Grades A, AA
4. Glass base—Grade G-5

When specifying laminated plastic tubing, the designer is concerned with relative balances of electrical, chemical and mechanical properties. When the degree of one or two desirable properties is emphasized, the relative strengths of other properties may be reduced somewhat. For example, Grade G-5 glass-base tubing, which provides high heat and arc resistance, exhibits less dielectric strength than Grade X paper-base.

In virtually all the applications of plastic tubing high strength-weight ratio is an outstanding factor in the specification of the material. The demand for a light material that will stand high stresses affords laminated plastics widespread application as component tubing.

As a fire extinguisher nozzle and as a television lens tube, for example, laminated plastic tubing is used in two apparently unrelated applications for the same reason—a high strength-weight ratio. Plastic television lens tubes stand hard use while adding little weight to already heavy mobile television cameras. Fire extinguisher nozzles (3¼-in. i.d. x 3½-in. o.d. x 25⅞-in. long) are made of Grade X paper-base rolled tubing. The plastic nozzles must and do resist chemicals and retain mechanical strength at low temperatures as well as add minimum weight to the apparatus.

Electrical Applications

The use of laminated plastic tubing has become common in the electrical field for communications, power and industrial electronics equipment. High dielectric strength, low power factor and high insulation resistance are several properties which make laminated plastics particularly useful as an insulator.

The easy machinability (about the same as brass) of thermosetting laminated plastics is important from a production standpoint. Most grades are easily punched, drilled, milled, turned and threaded. High structural strength and resistance to heat and moisture are valuable where power and communications equipment must operate under less than ideal conditions, such as moisture and abrasion in outdoor installations, and vibration, among other forces, in aircraft and rotating machinery.

At present, applications of plastic tubing in the electrical industry are as insulators for all types of switchgear equipment, coil forms for radio and television, instrument housings, bus bar coverings as well as many types and sizes of insulating bushings. Grades X and XX, rolled, are normally specified for bushings because of high dielectric strength and low moisture absorption plus good mechanical properties. Often in power installations exposed to all weather conditions, where low moisture absorption is especially important, Grades X or XX molded bushings are used.

The sizes of plastic tubing range from ½-in. long brush-holder bushings on fractional horsepower motors to 8-ft long insulating tubes over conductors on equipment as large as 33,333 kva, three-phase transformers. Heavy switch gear, disconnect switches, circuit breakers, and fractional horsepower motors of many

types utilize parts made with laminated plastic tubing. These tubes are also used in power control and service devices such as live line detectors fused trolley taps and fuse cases.

In power transformers, at ratings up to 15,000 kva, many turns of wire are supported on laminated plastic tubes in diameters as large as 6 ft. These tubes insulate the windings from each other as well as from the metal parts. Grade X paper base tubing is generally used in this application, although Grade A asbestos base tubes, with a higher heat resistance, are used where temperatures are relatively high.

In the radio and television manufacturing industries, laminated plastic tubing has fufilled the need for a good insulating material that is, at the same time, readily punched, drilled and threaded. A low power factor is especially important designwise and uniformity of wall thickness and diameter is a requisite in volume production. Laminated plastic coil forms in both transmitters and receivers are usually either Grade X or XX. Diameters range from ¼-in. i.d. and upwards, although the majority of these coil forms are less than ¾-in i.d. Concentricity of the inside and outside diameters of the tube is particularly important. Because concentricity is best achieved in rolled-type tubing, most thin-walled coil forms are so specified; coil form tubing machines readily.

Round tubing is the commonly used form. There are many applications, however, for oval, square, rectangular and even hexagonal tubing. Laminated plastic tubing including as many as eight separate rectangular cavities has been developed for special purposes. Rectangular and square tubes are frequently used for coil and condenser cases wherever space economy is important; for example, more rectangular tubes than round tubes of equal cross-sectional area can be fitted into a rectangular space.

Round laminated tubes are now used as oil-filled insulating ducts for three-phase underground transmission lines. The diameters of these tubes are usually in the range of 3 in. The underground ducts are normally made of either rolled Grade X or Grade XX paper-base laminated tubing because these grades retain high dielectric strength under humid conditions. The moisture absorption of Grade XX, when of the rolled type, is as low as 2.5% (tested according to A.S.T.M. Method D-348-46) with a 1/16-in. wall thickness. The corresponding dielectric strength of 1/16-in. wall Grade XX rolled tubing, for example, is from 400 to 500 v per mil on the short time test.

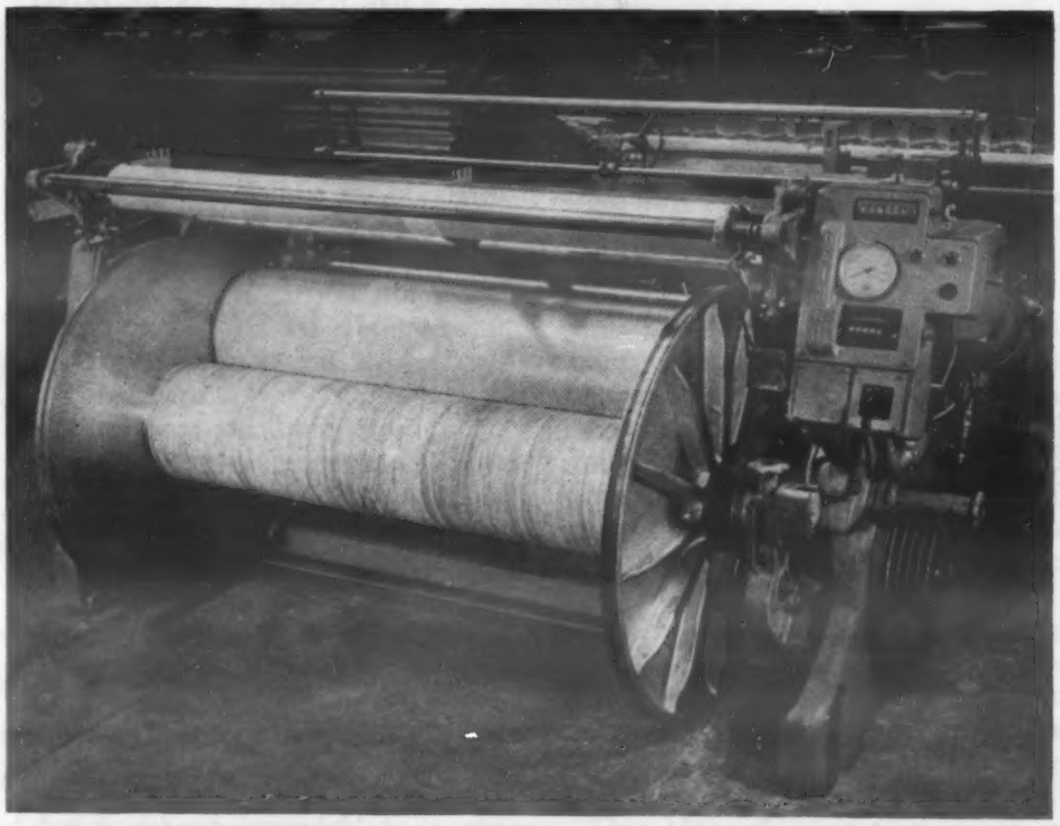
Another application of plastic tubing is in gas line bushings—often underground. Here, an additional function is performed, the prevention of electrolysis caused by stray eddy currents in the ground. Plastic gas line bushings, above ground, provide cathodic protection of delicate meters.

In the Chemical Field

Thermosetting laminated plastic tubing is widely used to transmit chemical solutions both in the chemical and oil industries. Molded Grades C and L tubes are commonly specified because these grades are characteristically chemical-resistant, highly moisture-resistant and retain size, shape and strength under long exposure to chemicals.

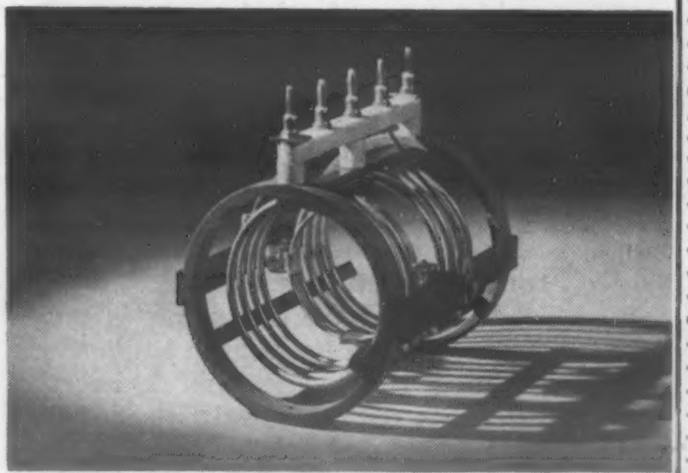
Of course, these materials are not entirely chemical-proof; as with any material, the extent of chemical resistance depends upon a number of conditions, among these the nature, temperature, and concentration of the chemical or corrosive agent. When properly specified, laminated plastic tubing is used for transmitting chemicals because of its long operating life and low installation and replacement costs. The tubing is produced in standard IPS sizes and is threaded by the manufacturer.

Anodizing baskets for aircraft rivets, spacers in color-film developing units, and tension rollers are also made of laminated plastic tubing. The



This large laminated plastic pressure roller is used in the textile industry.

Some typical tube forms in which thermosetting laminates are produced.



This air inductor coil for a radio transmitter is strongly supported by tough insulating rings made of Grade XX rolled laminated plastic tubing.

Characteristics of Laminated Plastic Tubing

Grade	Description		Tensile Strength,[1] Psi	Compressive Strength (axial),[1] Psi	Moisture Absorption,[1, 3] %	Dielectric Strength (short time test),[2] v/mil	Power Factor (at 10^6 cycles),[2] %	Dielectric Constant (at 10^6 cycles)[2]
X	Paper Base	Molded	10,000-12,000	14,000-16,000	2.0-2.5	400-500	3.0-4.0	4.7-5.3
		Rolled	9,000-11,000	9,000-11,000	2.5-3.5	500-600	2.5-3.5	3.5-4.0
XX	Paper Base	Molded	9,000-11,000	14,000-16,000	1.0-1.5	300-400	3.0-3.7	4.5-5.3
		Rolled	8,000-10,000	11,000-13,000	1.5-2.5	400-500	2.0-2.8	3.0-3.5
L	Fine Weave Fabric Base	Molded	7,500- 9,500	18,000-22,000	.80-1.2			
		Rolled	7,000- 8,500	14,000-16,000	2.0-3.5			
LE	Fine Weave Fabric Base	Molded	7,000- 9,000	22,500-27,500	1.4-2.0	350-450	3.5-4.5	4.5-5.0
		Rolled	6,200- 8,000	12,000-14,000	2.5-4.0	150-250	3.5-4.5	4.0-4.5
C	Fabric Base	Molded	8,000-10,000	18,000-22,000	1.0-1.5			
		Rolled	7,500- 9,000	14,000-16,000	2.0-3.5			
CE	Fabric Base	Molded	7,500- 9,500	22,500-27,500	1.4-2.0	250-350	3.5-4.5	4.5-5.3
		Rolled	7,000- 8,500	12,000-14,000	2.5-4.0	100-200	3.5-4.5	4.0-4.5
A	Asbestos Paper Base	Molded	7,000- 8,500	18,000-22,000	0.3-0.7	100-150		
		Rolled	5,500- 6,500	14,000-16,000	1.5-2.5	100-150		
AA	Asbestos Fabric Base	Molded	7,000- 8,500	22,500-27,500	0.3-0.7	90-125		
		Rolled	5,500- 6,500	18,000-22,000	1.5-2.5	100-150		

[1] *ASTM Method D-348-46.*
[2] *ASTM Method D-150-47T.*
[3] *Conducted on sample tubes, 1 in. i.d. x 1⅛ in. o.d. x 1 in. long.*

anodizing baskets are made of molded fabric-base laminated tubing, 18-in. long and 6⅝-in. o.d., with circulating holes drilled through the tube walls. The spacers in the developing unit, also molded-type fabric base tubing, are installed to hold film rollers in position and are therefore exposed to highly corrosive chemical solutions. Tension rollers used in processing synthetic yarns have been made by covering and sealing a steel shell (22-in. i.d.) with Grade L fabric-base laminated tubing. In each of these applications, chemical resistance and mechanical strength are essentials which dictate the choice of laminated plastic tubing.

As Mechanical Components

Extensive use of laminated plastic tubing as mechanical components is based principally upon the high strength-to-weight ratio of the material. The high tensile and compressive strengths given in the accompanying table for eight of the ten grades are obtained with a weight ½ that of aluminum and 1/7 the weight of an equal volume of steel.

Laminated plastic tubing is now widely used as bearings in equipment such as landing gear shock structs, dredge scoops, vertical mixed flow pumps and outboard motors. Grade L, molded, is normally specified as a bearing material in these applications because of its low moisture absorption and high compressive strength—18,000 to 22,000 psi—in the axial direction. In addition, good chemical resistance is important where bearings are exposed to corrosive solutions; this is true of a pivot bearing, for example, on an outboard motor exposed for long periods to salt water.

The application of laminated plastic tubing requiring probably the closest tolerances in fabrication are high-speed ball-bearing retainer rings in aircraft, instruments and precision machine tools. Need for dimensional stability, as well as light weight and high stress characteristics, prompted the designers to specify Grade L rolled laminated plastic tubing. The easy machinability of this grade makes it practical to maintain the tolerances, while a low coefficient of expansion (compared with metals) results in a minimum change in dimensions as the retainer ring is heated during operation. The plastic exhibits complete resistance to chemical attack by lubricants.

In the Textile Industry

Designers of textile machinery, when specifying materials for most component tubing, think in terms of high strength, light weight, good chemical resistance, moisture resistance and smooth surfaces. Grade XX rolled plastic tubes combine these characteristics and are now in general use as barrels of standard winder-spinner bobbins, draw twister pirns, take-up arbors and nylon-sizing bobbins. As auxiliary equipment in textile manufacture, drier poles and dye sticks use similar tubing to cover a metal core.

Grade C molded tubes, which pipe sizing solutions (polyvinyl alcohol, etc.) to nylon-sizing machines, withstand chemical action in solution, are mechanically strong as compared with glass, and much lower in cost than stainless steel. Grade XX rolled tubes are used as nylon-sizing bobbins (5⅝-in. i.d. x 6⅛-in. o.d. x 7 in. long) to withstand the crushing action of the drying nylon and the corrosive action of the size. They cannot stain the yarn, and are readily machined to a smooth, non-snagging surface.

As barrels for winder-spinner bobbins, Grade XX rolled tubes are designed for resistance to crushing and for a smooth finish. Their uniform structure results in a well-balanced bobbin, and the impact resistance of the material withstands abuse in the mill. Because the radial pressures of the tightly wound nylon yarns are very high, maple bobbins have been known to distort under load. Grade XX rolled bobbins have been found to stand extreme radial compression.

Snagging of fine nylon yarns on bobbins barrels, which often results in breaks and costly production delays, has been avoided by the use of highly polished laminated plastic bobbins for handling 10 and 15 denier monofilament hosiery yarns. The paper-base tubing, either rolled Grade X or XX, is first turned in a lathe, then sanded, fine-sanded and polished.

Materials & Methods Manual 65

This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and application

Welding Electrodes and Rods
—for Ferrous and Nonferrous Metals

by H. R. Clauser, Managing Editor, Materials & Methods

One of the most important requirements for producing a satisfactory welded joint is use of the proper filler metal. Selecting the proper filler metal is often quite difficult because of the many variables involved, and because of the great number of available electrodes and welding rods from which to choose. This Manual, therefore, is intended as a guide for those faced with the problem of filler metal selection. It covers the standard type electrodes and welding rods for joining all the common ferrous and nonferrous metals and alloys, including irons and steels, copper-base alloys, aluminum, magnesium, nickel alloys, zinc and lead.

Contents

Introduction

This drawing shows a coated arc-welding electrode in the process of depositing weld metal. Note how the coating and formation of slag protects the weld metal. (Courtesy General Electric Co.)

Producing a good, sound weld depends to a great extent on selecting the electrode or welding rod that is best fitted for the particular metal, welding process and operating conditions involved. This is often a difficult job, because of the many variables and because of the variety of different types of rods and electrodes from which to choose.

The purpose of this manual, therefore, is to serve as a guide to the proper selection of filler metals for welding the common ferrous and nonferrous metals and alloys. It will not include those electrodes and rods used primarily for hard-facing, since this subject has already been covered in Manual No. 27, Hard-Facing Materials (MATERIALS & METHODS, June, 1947). Nor does space permit the inclusion of brazing alloys. The latter will be taken up at a later date.

Obviously, this article cannot give all the information needed to make final selections for specific jobs. But it can help by pointing out the principal characteristics and properties of the various types of filler metals. After that, on-the-job advice on specific problems must be sought from the manufacturers of electrodes and rods.

A word or two should be said about the terms "filler metal," "electrode," and "rod." Filler metal is the broad term referring to the metal to be added in making a weld. Electrode and welding rod are narrower in their meaning.

Electrode in this manual refers to filler metal in wire or rod form which is used in arc-welding processes and which carries the current to produce the welding arc. Electrodes can be either bare, wash-coated, or covered with a relatively thick coating composed of minerals, organic chemicals, and, sometimes, powdered alloying elements. The trend has been toward the use of heavy covered electrodes for shielded metal-arc welding wherever applicable because of the advantages gained. The coating provides protection for the molten metal from the atmosphere, improves properties of the weld metal, aids in striking arc, and stabilizes the arc.

Welding rods are filler metals in wire or rod form used in gas-welding and in those arc-welding processes in which the electrode does not furnish the filler metal. Welding rods are generally bare.

In choosing a filler metal for a particular job, there are numerous factors that must be considered. These include:

1. Type and composition of the metal being welded.
2. Welding process.
3. The mechanical and/or physical properties of the resultant weld.
4. The welding conditions, which include type of joint, fit-up, welding position, current and polarity, penetration characteristics, and deposition rate.
5. Weld appearance.

The above factors are of fundamental importance, can be fairly closely evaluated, and are often covered in filler metal specifications. However, there are a number of variables in electrodes and rods that are more difficult to evaluate. Some of these are ease of striking arc, arc stability in different positions, amount of spatter, "feel" of the arc, welding skill required, and amount of fumes and smoke. These more intangible factors frequently influence final filler metal selection. Little can be said about them in this manual, and the user generally relies on personal preference and on producers for information on these factors.

Filler Metals for Steels and Irons

Mild and Low Alloy Steels

Arc-welding electrodes for mild steels and low alloy steels are best described by discussing the specifications which have been established by joint action of the American Welding Society and the American Society for Testing Materials. They are "Mild Steel Arc-Welding Electrodes" (AWS Designation A5.1; ASTM Designation A233) and "Low-Alloy Steel Arc-Welding Electrodes" (AWS Designation A5.5; ASTM Designation A316). The specifications are now universally accepted. Without them as a guide, the user would be faced with the almost impossible task of choosing from a confusingly large number of similar electrodes, each identified by a different trade name.

The specifications separate and classify electrodes according to (a) mechanical properties of deposited metal, (b) operating characteristics, and (c) type of covering. Together they divide electrodes into six major classifications

or series according to minimum tensile strength as shown in Table 1.

Each major series is further subdivided according to operating characteristics. The major operating characteristics of all standard electrodes for welding mild and low alloy steels are given in Table 2. It should be noted that electrodes in different tensile strength series can have essentially the same operating characteristics. Thus, E6010, E7010, E8010, E9010 and E10010 electrodes have essentially the same operating characteristics as given in the table.

All electrodes, regardless of trade name or make, falling into any one classification can be expected to have major characteristics which are similar, if not identical. Thus, the user, after determining the classification that best fits his particular application requirement, can limit his selection to the commercial electrodes that fall within that classification.

Practically all electrodes for welding mild and low alloy steels have essentially the same composition core wire. It is a good grade of low carbon rim steel with the following analysis: 0.10 to 0.14 carbon, 0.40 to 0.60 manganese, 0.04 max sulfur and phosphorus, and 0.025% max silicon. The coating, however, differs from one classification to another and provides the variations in mechanical properties and operating characteristics. In the low alloy steel electrodes the coating is also used to control the chemical analysis and thermal characteristics of

Table 1—Classification of Mild and Low Alloy Steel Electrodes

Specification				
AWS	ASTM	Classification	Minimum Tensile Strength, Psi	Elong, % in 2 In.
A5.1	A233	E45XX	45,000 (as-welded)	5
A5.1	A233	E60XX	62,000 (as-welded)	17-25
A5.5	A316	E70XX	70,000 (str. relieved)	18-25
A5.5	A316	E80XX	80,000 (str. relieved)	16-22
A5.5	A316	E90XX	90,000 (str. relieved)	14-20
A5.5	A316	E100XX	100,000 (str. relieved)	13-18

the weld metal. The E45XX electrodes are either bare or are covered with a very light wash or powder coating.

A few words should be said here about the lime-ferritic or so-called low-hydrogen electrodes. In the AWS-ASTM classification they form the EXX15, EXX16 classifications in the different tensile strength series. Low-hydrogen electrodes have a core wire similar to other mild steel and low alloy steel electrodes, but are different in that the coating consists of minerals low in hydrogen. This coating gives to these electrodes definite advantages over the conventional coated types. They are capable of welding a variety of steels under many different conditions. They minimize the tendency for underbead cracking. They eliminate or minimize the preheat usually necessary in welding higher carbon and low alloy steels. And they produce welds with better mechanical properties. These, and other advantages, have resulted in their wide acceptance for welding a variety of carbon and low alloy steels.

Carbon Steels

Mild steel electrodes (E60XX series) are universally used for welding low carbon steels. The mechanical properties of weld deposits that can be expected with mild steel electrodes are given in Table 3. It can be seen that differences between the various electrodes in this series are relatively small. Therefore, the specific type selected from the series depends largely on the operating conditions involved.

Classifications E6010 and E6012 are suitable for a vast majority of applications, and together constitute 65% of all electrode production. Where maximum welding speeds are important, E6012, 13, 15, 16, 20 and 30 are generally recommended. When welding light gage metal, E6012 and E6013 are best for lap or T-type fillet joints, while E6010 or E6012 are best for edge type joints. Classifications E6020 and E6030 generally provide highest welding rate and best quality welds, but their use is restricted to downhand, horizontal work.

Table 2—Mild Steel and Low Alloy Steel Electrodes Operating Characteristics

Electrode Classification	Coating	Current and Polarity	Position and Fit-Up Useability	Arc Characteristics	Deposit Appearance	Deposition Rate	Slag Removal
EXX10	High cellulose sodium	D.c., rev. polarity	All position	Spray type, deep pene.	Flat, rippled	Slow	Thin Good
EXX11	High cellulose potassium	A.c. or d.c. rev. polarity	All position	Spray type, deep pene.	Flat, rippled	Slow	Thin Good
E6012	High titania sodium	D.c. straight polarity, or a.c.	All position, poor fit-up	Globule type, med. pene.	Convex, rippled	Medium	Heavy Fair
EXX13	High titania potassium	A.c. or d.c. straight polarity	All position, poor fit-up	Globule type, shallow pene.	Flat or concave, slight ripple	Med. fast	Medium Excellent
EXX15	Low hydrogen sodium	D.c. rev. polarity	All position	Globule type, med. pene.	Flat, wavy	Medium	Medium Excellent
EXX16	Low hydrogen potassium	A.c. or d.c. rev. polarity	All position	Globule type, med. pene.	Flat, wavy	Medium	Medium Excellent
EXX20	High iron oxide	A.c. or d.c. straight polarity	H-fillet and flat	Spray type, med. pene.	Flat or concave, smooth	Fast	Heavy Excellent
EXX30	High iron oxide	D.c., either polarity or a.c.	Flat only	Spray type, deep pene.	Flat, smooth	Fast	Heavy Excellent

XX = 60, 70, 80, 90, 100

Table 3—Mild Steel Electrodes—Mechanical Properties
(As-Welded)

Electrode	Tensile Strength, Psi	Yield Strength, Psi	Elong, %	Impact Res. Ft-Lb, Izod	Endurance Limit, Psi	Hardness, Bhn
E4510-20	50,000-60,000	42,000-50,000	8-10			
E6010	62,000-70,000	52,000-58,000	22-28	50-70	28,000-32,000	146-160
E6011	62,000-73,000	52,000-61,000	22-28	50-70	28,000-32,000	146-160
E6012	68,000-78,000	55,000-65,000	17-22	25-50		150-170
E6013	68,000-78,000	55,000-65,000	17-22			150-170
E6015 E6016	68,000-76,000	55,000-62,000	22-35	70-130		140-160
E6020 E6030	62,000-68,000	52,000-58,000	25-30	50-70	30,000-34,000	150-170

In welding medium and high carbon steels, where carbon content ranges from about 0.35 to 0.95%, obtaining a sound weld becomes more difficult. Electrode selection must be made, keeping in mind the tendency for underbead and weld cracking. The low penetrating type electrode, E6012, can frequently be used successfully. However, where cracking occurs with E6012, electrodes of the low-hydrogen types, E6016 and E7016, are recommended. In applications where for some reason E6010, 11 or E7010, 11 must be used, some preheat and a low penetrating technique is required.

Low Alloy Steels

The E70, E80, E90 and E100 series are the basic types of electrodes available for welding low alloy steels. However, it should be remembered that the AWS-ASTM classification of low alloy steel electrodes applies only to operating characteristics and mechanical properties. For many low alloy steel weldments, an important requirement is to get a weld deposit having a certain analysis and/or certain thermal characteristics. Because of the great variety of compositions that can be deposited by electrodes of a given classification, it is necessary in such cases for the user to carefully select the type and brand of electrode which best meets his requirements.

The E60XX electrodes, particularly E6010 and 11, can be used on low alloy steels in thicknesses up to ¼ in. where the migration of alloying elements from the base metal into weld metal raises its strength so that the reinforced weld will produce a joint strength about equal to the base metal.

The operating characteristics of low alloy steel electrodes are similar to those of the mild steel electrodes and are given in Table 2. As mentioned previously, because of the many variable conditions involved, it is impossible to make specific recommendations on electrodes to use for each of the various alloy steels. However, following are a few general comments.

Nickel Steels—In welding the lower carbon and nickel grades, where tensile strength similar to the base metal is required, a high tensile E7010, 20 electrode can be used. Standard E6012 electrodes can often be used on thin sheets in the low carbon grades. Where a weld deposit analysis similar to that of the base metal is required, special electrodes to meet such requirements are used. Low-hydrogen electrodes can

Mild Steel Electrodes—Relationship of Usability, Performance and Quality Characteristics Provided by Various AWS Classifications

Characteristic	Increasing Values → AWS Classification								
Tensile Strength	E6030		E6020	E6010		E6011	E6013		E6012
Ductility	E6012		E6013	E6010		E6011	E6020		E6030
Penetration	E6013		E6012	E6011		E6010	E6020	and	E6030
Absence of Undercutting	E6010	and	E6011	E6020	and	E6030	E6012		E6013
Absence of Spatter	E6010		E6011	E6012		E6013	E6020	and	E6030
Deposition Efficiency	E6020	and	E6030	E6011		E6010	E6012	and	E6013
Deposition Rate	E6010		E6011	E6013		E6012	E6020	and	E6030
Soundness	E6012		E6013	E6010		E6011	E6020	and	E6030
Arc Force	E6013		E6012	E6011		E6010	E6020	and	E6030
Ease of Handling	E6010		E6011	E6020	and	E6030	E6012		E6013
Ease of Restriking Arc	E6020	and	E6030	E6011		E6010	E6012		E6013
Current Capacity	E6010	and	E6011	E6013		E6012	E6020	and	E6030
***Flux-to-Steel Ratio**	E6010		E6011	E6012		E6013	E6020	and	E6030

* *Flux-to-steel ratio* $= \frac{\textit{Weight of covering}}{\textit{Weight of steel}}$, *and is usually in proportion to the thickness of the covering.*

Courtesy General Electric Co.

be used effectively on nickel steels to reduce the tendency for cracking.

Molybdenum Steels—These steels are frequently used for the high creep strength they provide. In such cases, molybdenum should be present in the deposit. Low carbon grades (below 0.18% carbon) can be welded with E7010, 12, 20 carbon-molybdenum electrodes to give a tensile strength in the as-welded condition similar to that of the plate metal. Where tensile strength of the weld need not be as high as the base metal, E6010 electrodes have proved satisfactory. On higher carbon and alloy grades where the weld properties must be similar to the base metal after heat treatment, special electrodes must be selected that will deposit the proper analysis. Low-hydrogen types are generally used to reduce the tendency for cracking.

Nickel-Chromium Steels—On lower carbon grades, E7010, 15, 16 and E10010 class electrodes can be used to give as-welded strengths similar to the base metal. When heat treating is involved, electrodes must be selected so that weld-metal composition will yield properties similar to the base metal after heat treatment. When it is necessary to weld nickel-chromium steels containing above about 0.40% carbon, austenitic 25-20 (E310-15) electrodes should be used.

Low Alloy-High Strength Steels—Ordinary mild steel electrodes can be used on most of the low alloy-high strength structural steels. The low penetrating E6012 type is frequently recommended. Where higher strength and ductility are desired, low alloy steel electrodes in the required tensile strength class are used. Where superior weld properties are required and the tendency for cracking must be minimized, low-hydrogen type electrodes are preferable. Austenitic 25-20 electrodes (E310-15) also produce superior welds, but their higher cost limits their use to very special applications.

Chromium Steels—Chromium-molybdenum and carbon-molybdenum electrodes are usually used. Where carbon content is low, E6012 or E7015, 16 low-hydrogen electrodes are often satisfactory. When it is necessary to weld these steels having carbon above 0.30%, the use of 25-20 austenitic electrodes is often necessary to obtain a satisfactory weld.

Silicon Steels—In structural work done in all positions, E6010, 11 or E7010, 11 are usually used, but care must be taken to limit carbon content. If work can be positioned for downhand welding, E7020, 30 electrodes are most satisfactory. For fast production, E6012 or the low hydrogen types are most suitable.

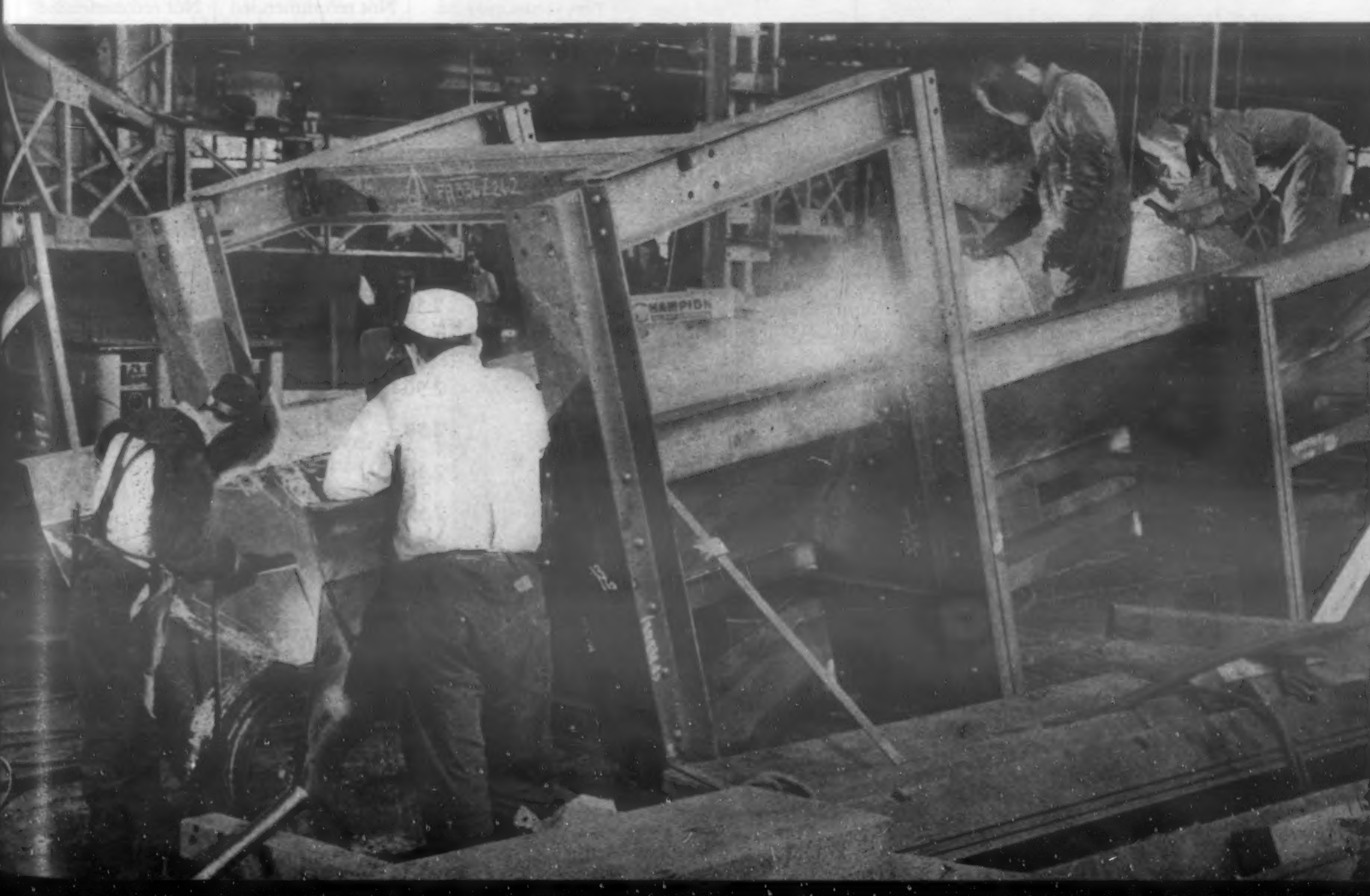
High Sulfur Steels—In general, the low hydrogen E6015, 16 type electrodes give best results because high sulfur increases the tendency for cracking. Low penetrating E6012 type can also be used successfully in certain applications.

Corrosion Resisting Steels and Irons

In selecting filler metals for welding corrosion resisting steels, the most important consideration generally is weld metal composition. In many applications it is necessary to obtain a weld deposit that has corrosion resistant properties at least equal to those of the base metal. Usually, an electrode which produces the same analysis as the base metal being welded will give comparable, if not slightly higher, corrosion resistance. However, in applications where other factors are involved, it may not be possible to use a filler metal of the same analysis as the base metal, and in such cases the selection problem is more difficult.

The American Welding Society and the American Society for Testing Materials have set up ten standard classes of arc-welding electrodes for chromium-nickel steels and straight chromium steels in the specification for "Corrosion Resisting Chromium and Chromium-Nickel Steel Welding Electrodes" (AWS Designation A5.4; ASTM Designation A298). They are E308, E309, E310, E316, E317, E330, E347, E410, E430 and E502. While these standard classes of electrodes are intended to cover the principal grades of corrosion

Whenever possible, work should be positioned for using electrodes in the downhand welding position. (Courtesy The Champion Rivet Co.)



In gas welding, the filler metal in the form of rod or wire is fed into the gas torch flame.

resisting steels, there are other commercial electrodes available.

The chemical composition of all-weld metal obtained with the standard electrodes is given in Table 4, taken from the AWS-ASTM specification. Table 5 gives their operating or usability characteristics, also taken from the AWS-ASTM specifications.

The appendix to the AWS-ASTM specification describes in some detail each of the standard classes, and what follows is a somewhat condensed discussion from that appendix.

E308 Series—The nominal composition of the weld metal is 19 chromium, 9% nickel. Commercial specifications vary in the minimum alloy requirements of this alloy, and, consequently, the names 18/8, 19/9 and 20/10 are often associated with electrodes of this series. The letter S is often added to the 18/8, 19/9 or 20/10 names to designate the low-carbon grade (0.08% max) as compared with the higher carbon grade (0.20% max). Electrodes of this series are most often used to weld alloys of similar composition. When it is required to weld 18 chromium, 8% nickel alloys whose carbon content is not restricted to 0.08% max, electrodes of the E308 series are used, but in these applications the restriction as to carbon content in the weld metal is not essential.

E309 Series—The nominal composition of the weld metal is 25 chromium, 12% nickel. In the wrought form, however, chromium is usually reduced in order to make the alloy more fully austenitic. Sometimes columbium is added to stabilize the carbides. The electrodes in this series are commonly used for welding similar alloys in wrought or cast forms. Occasionally, they are used to weld 18:8 base metals when severe corrosion conditions exist which require higher alloy content weld metal. They are also used in welding dissimilar metals, such as joining 18:8 to mild steel, welding the clad side of 18:8 clad steels, and applying sheet linings of 12% chromium steels to mild steel shells.

E310 Series—The nominal composition of the weld metal is 25 chromium, 20% nickel, but sometimes additions of columbium and molybdenum are made. These electrodes were originally designed to weld alloys of similar composition. More recently these electrodes have found extensive use in the welding of hardenable steels. Because of their higher alloy content, these electrodes are often used for welding clad steels, in order to offset the effect of dilution when the weld fuses to the carbon steel backing. For the same reason these electrodes are often used for welding 18 chromium, 8% nickel

Table 5—Corrosion Resisting Steel Electrodes Usable Positions and Types of Current

(Spec. AWS A5.4, ASTM A298)

Usability Designation*	Direct Current: Flat and Horizontal Fillet	Direct Current: Vertical and Overhead	Alternating Current: Flat and Horizontal Fillet	Alternating Current: Vertical and Overhead
—15	All sizes	5/32 in. and smaller	Not recommended	Not recommended
—16	All sizes	5/32 in. and smaller	All sizes	5/32 in. and smaller
—25	All sizes	Not recommended	Not recommended	Not recommended
—26	All sizes	Not recommended	All sizes	Not recommended

* *Usability designation follows the series identification. For example, E310-15.*

Table 4—Corrosion Resisting Welding Electrodes—Chemical Requirements for All-Weld Metal

(Spec. AWS A5.4, ASTM A298)

Series	Carbon, Max, % [a]	Chromium, %	Nickel, %	Molybdenum, %	Columbium, %	Manganese, Max, %	Silicon, Max, %	Phosphorus, Max, %	Sulfur, Max, %
E308	0.08	19.0 min	9.0 min	—	—	2.50	0.75	0.030	0.030
E309	0.15	22.0 min	12.0 min	—	—	2.50	0.75	0.030	0.030
E310	0.20	25.0 min	20.0 min	—	—	2.50	0.75	0.030	0.030
E316	0.08	17.0 min	11.0 min	1.75 to 2.50	—	2.50	0.75	0.030	0.030
E317	0.08	18.0 min	12.0 min	3.00 to 4.00	—	2.50	0.75	0.030	0.030
E330	0.25	14.0 min	33.0 min	—	—	2.50	0.75	0.030	0.030
E347	0.08	18.0 min	9.0 min	—	10 x C, 1.20 max	2.50	0.80	0.030	0.030
E410	0.12	11.0 min	0.60 max	—	—	0.60	0.75	0.030	0.030
E430	0.10	15.0 min	0.60 max	—	—	0.75	0.75	0.030	0.030
E502	0.10	4.0 to 6.0	0.40 max	0.45 to 0.65	—	0.75	0.75	0.030	0.030

[a] *Carbon shall be analyzed to the nearest 0.01%.*

steels to carbon steel.

E316 Series—Nominal composition of the weld metal is 18 chromium, 12 nickel and 2% molybdenum. Commercial specifications vary in the minimum alloy requirements, and, consequently, the names 18:8 Mo or 18:8 SMo are often associated with electrodes of this series. These electrodes should not be confused with the less common of the chromium-nickel-molybdenum alloys containing 3 to 4% molybdenum. Electrodes of the E316 series are usually used for welding similar alloys (about 2% molybdenum) but are sometimes found applicable for the higher alloy composition (about 3% molybdenum). They have been successfully used in applications involving special alloys for high-temperature service, and in pulp and paper industry where parts come in contact with sulfites. The presence of molybdenum provides increased creep resistance at elevated temperatures.

E317 Series—The alloy content of this series is somewhat higher than the E316 series, particularly in molybdenum content. They are usually used for welding alloys of similar composition. Their use is usually limited to severe corrosion applications involving sulfuric and sulfurous acids and their salts.

E330 Series—Nominal composition of this series is 35 nickel, 15% chromium. Since nickel is the predominant element, it is commonly used for heat- and scale-resisting properties at temperatures above 1800 F. Repairs of defects in alloy castings and the welding of both castings and wrought alloys of similar composition are the most common applications.

E347 Series—Nominal composition of the weld metal is 19 chromium, 9% nickel, with columbium added as a stabilizer. Commercial specifications vary in the minimum alloy requirements, and, consequently, the names 18:8 Cb, 18:8 SCb and 19:9 SCb are often associated with electrodes of this series. The alloy is also referred to as a stabilized 18:8 or 19:9 alloy, indicating that it is not subject to intergranular corrosion resulting from carbide precipitation. The electrodes of this series are usually used for welding chromium-nickel alloys of similar composition stabilized either with columbium or titanium. Electrodes depositing titanium as a stabilizing element are not now commercially available because titanium is not readily recovered in the weld metal.

E410 Series—This 12% chromium alloy is an air-hardening steel, and, therefore, requires preheat and postheat treatments in order to achieve welds of adequate ductility for most engineering purposes. The most common application of electrodes of this series is for welding alloys of similar composition. They are also used for depositing overlavs on carbon steels for corrosion, erosion or abrasion resistance, such as occurs in valve seats and other valve parts.

E430 Series—Electrodes in this series generally contain between 15 and 17% chromium, although the maximum limit is not specified. The composition is balanced by providing sufficient chromium to give adequate corrosion resistance for the usual applications and yet retain sufficient ductility in the heat-treated condition to meet the mechanical requirements of the specifications. (Excessive chromium will result in lowered ductility.) Welding with these electrodes usually requires preheating before welding and a postheat treatment after welding. Optimum physical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation. Their chief application is for alloys having a similar composition.

E502 Series—Electrodes in this series of classifications contain 4 to 6% chromium and about 0.50% molybdenum, and are used for welding material of similar composition, usually in the form of pipe or tubing. The alloy is an air-hardening material, and, therefore, when welding with the E502 series of electrodes, preheating and postheat treatment are strongly recommended.

Nickel-Chromium Steels — As indicated earlier, it is generally preferable to select from the above electrodes one which produces a deposit of the same general analysis as the base metal. In welding grades 301, 302, 303, 304 and 308, either E308 or E347 electrodes can be used. For grade 309, electrode type E309 depositing a 25 chromium-12% nickel analysis is usually used. E310 can also be used. Grade 310 is normally welded with E310 electrodes. On grades 316 and 317, E317 Mo electrodes that deposit approximately the same analysis as the

Hull members of an Army tank on a positioner being arc-welded. Special electrodes are required for welding the armor plate. (Courtesy The Lincoln Electric Co.)

Table 6—Gas Welding Rods for Irons and Steels

Metal	Welding Rod
Low and High Carbon Steels	Steel
Cast Steel	Steel
Manganese Steel	Base metal comp.
Wrought Iron	Steel
Galvanized Steel	Steel Bronze (braze welding)
Gray Cast Iron	Cast iron Bronze (braze welding)
Malleable Cast Iron	Bronze (braze welding)
Chromium-Nickel Steel (18:8 and 25:12)	Base metal comp. or Cb stab. stainless
Chromium Steel	Base metal comp. or Cb stab. stainless
Chromium Iron	Base metal comp. or Cb stab. stainless
Chromium-Nickel Castings	Base metal comp. or 25:12 Chromium-nickel steel

Table 7—Iron and Steel Gas Welding Rods Tensile Requirements of Deposited Metal

Welding Rod Classification Number	Plate Thickness, In.	Treatment of Welded Specimen *	Tension Test Requirements: Tensile Strength, Min, Psi	Tension Test Requirements: Elongation in 2 In., Min, %
GA65	3/4	SR	65,000	20
		NSR	72,000	17
GA60	3/4	SR	60,000	25
		NSR	62,000	20
GA50	3/4	SR	50,000	28
		NSR	52,000	23
GB65	3/4	SR	65,000	18
		NSR	72,000	15
GB60	3/4	SR	60,000	20
		NSR	62,000	15
GB45	3/8	NSR	45,000	—

(3/16- or 1/4-in. Welding Rods)

* *SR and NSR signify stress-relieved and non-stress-relieved, respectively.*

base metal are used. Grades 347 and 321 are welded with E347 Cb stabilized electrodes.

Straight Chromium Steels—The straight chromium steels can be welded with either straight chromium filler metal of the E410, E430 and E502 classes, or with austenitic electrodes. The general rule is to choose an electrode which will give a weld with service properties at least equivalent to those of the base metal. Filler metals of straight chromium analyses have the advantage of providing a weld having the same coefficient of thermal expansion as the base metal; therefore, they can be more nearly completely stress relieved than welds made with austenitic electrodes. However, by using austenitic electrodes, fabricating problems are lessened, because the weld metal does not harden upon quenching and has a high degree of notch toughness, thus reducing the possibility of cracking. When welding these steels with austenitic electrodes, the deposit should be sufficiently high in nickel and chromium to allow for dilution, which results from mixing with base metal.

Cast Irons

Several different types of electrodes and rods find use for welding cast iron. At present, nickel core electrodes are often used. They are available for use with either d.c. or a.c., and can be used in any welding position. The resulting weld deposit is more ductile compared to cast iron, and is readily machinable. It does not give a full color match. On thick sections the weld is sometimes susceptible to cracking. Monel-core electrodes have also been used occasionally on cast iron. Phosphor bronze electrodes are widely used for repair welding of cast iron.

Electrodes having a cast iron core also can be used. They require high heat input, and, therefore, are primarily used on preheated parts. Coated electrodes with a mild steel core, such as E6010, are used to a limited extent. The strains from such electrode deposits are high and increase the probability of cracking. Such welds are usually not machinable.

For gas-welding, cast iron filler metal is used in the form of square or round cast bars. Their composition is usually controlled so that the melting point is as low as practicable, and so that they are free of nonmetallic inclusions, and low in phosphorus (0.4-0.7%) and sulfur (0.08% max).

For applications where the weld is not subject to atmospheric or electrolytic corrosion or to thermal stresses, braze welding can be used employing copper alloy rods such as Naval brass and manganese bronze. They are used extensively for repair welding cast iron parts. The big advantage of using nonferrous filler metals is that their melting point is several hundred degrees lower than cast iron, thus reducing the heat effects from welding. The strength of braze welded joints is generally comparable to that obtained with cast iron filler metal. Where a good color match is desired, nickel-silver can be used.

Wrought and Ingot Iron

Filler metal conforming to GA60 and GB60 classes in the joint AWS-ASTM specifications for "Iron and Steel Gas-Welding Rods" are suitable for welding wrought iron. For arc-welding, electrodes in the E60XX mild steel series can be used. Electrodes should have sufficient quantities of carbon, manganese and silicon to compensate for any losses of these elements during welding.

Electrode choice for ingot iron should be made on the same basis as for mild steel. For sheet less than ⅛-in. thick, all-position electrodes can be used. Gas-welding of ingot iron is quite similar to gas-welding of low-carbon steel, and welding rods of same analysis as the base metal prove most satisfactory.

Cast Steels

In general, selecting a filler metal for welding cast steels requires consideration of the same factors applicable in the case of wrought steels. In welding ferritic cast steels, the filler metal is generally selected on the basis of mechanical properties. However, where high temperature service is involved, the filler metal must often match that of the base metal to provide comparable high temperature properties.

Braze welding is also used on ferritic cast steels. The filler metal is

Naval brass, the same as for cast iron, except for small additions of other elements to make it nonfuming.

Cast austenitic steels are most generally used for corrosion resistance and for service at elevated temperature. Therefore, filler metal selection is usually more critical than in the case of ferritic steels. In general, the earlier discussion on corrosion resistant electrodes for wrought steels also applies to austenitic cast steels.

Austenitic manganese cast steels can only be arc-welded. The following types of electrodes can be used: bare or covered nickel-manganese electrodes; covered austenitic stainless steel electrodes; low-carbon steel electrodes with high manganese covering; and composite electrodes with high manganese filler (with or without nickel) in a low-carbon steel tube.

Welding Rods for Irons and Steels

Gas-welding rods are available for welding practically all the ferrous metals. In general, selection should be made so that the properties of the deposited metal match those of the base metal, keeping in mind that certain allowances must be made in the rod composition for changes occurring during the welding. Table 6 lists the welding rod metals generally used in welding the common ferrous metals.

Gas-welding rods for carbon and low-alloy steels are covered by a joint AWS-ASTM specification, "Iron and Steel Gas-Welding Rods" (AWS Designation A5.2; ASTM Designation A251). The rods are classified on the basis of ultimate tensile strength of the deposited metal in the stress-relieved condition, as shown in Table 7.

In welding chromium-nickel and straight chromium corrosion resisting materials with oxyacetylene, inert-gas-shielded arc, or atomic hydrogen methods, filler metal is frequently required. In general, the composition of the rods that are used are comparable to that used for electrode core wire. Since the rods are not coated, the alloying elements required in the weld deposit must be present in the wire itself; and if losses occur during welding, these must be compensated for by increasing the alloy content of the wire.

Rods used with the inert-gas-shielded arc process generally are of the base metal composition, but variations from this are necessary for specific applications. If maximum corrosion resistance is desired without heat treatment after welding, type 347 rods should be used for grades 301, 302, 304, 308, 321 and 347. To minimize the tendency for hot cracking in the high nickel content types, a type of 312 or 312 Mo rod is frequently used.

Submerged Arc Welding Electrodes

The filler metals used with this process are in the form of bare rods or bare wire in coils. The surface is clean and bright, and often lightly copper-coated to improve contact and prevent rusting. The following types of wire are available for welding various metals.

Low carbon steel—for welds in 55,000 to 65,000 psi tensile steels, and in high tensile steels if stress relief is not required.

Low carbon alloy steel—for welds in 70,000 psi and other high tensile steels.

Special alloy steels — for meeting chemical composition requirements of SAE constructional steels.

Stainless steels and nonferrous alloys —available in compositions to match the base metal.

High carbon and high carbon alloy steels—for surfacing.

The use of the proper flux or melt in combination with these filler metals is most important. As with covered electrodes, alloying elements are sometimes in the flux to obtain certain required properties in the weld deposit.

Galvanized iron exhaust stack fabricated with aluminum bronze electrodes. (Courtesy Ampco Metal, Inc.)

In atomic hydrogen-arc welding, the filler metal is fed into the welding arc as shown here. (Courtesy General Electric Co.)

Filler Metals for Copper-Base Alloys

The copper-base alloys most commonly used in fabrication are weldable by one or more of the welding processes. While the filler metals used are in some cases similar in composition to the alloy being welded, there are usually differences in analysis in order to improve the welding characteristics, to control the weld properties, and to compensate for losses of alloying elements in the welding operation. Since the oxides of copper, tin, aluminum and other alloying elements are difficult to remove from the weld metal, the use of proper fluxes either separately or in the coatings is usually required.

All of the common copper-base alloys, except the brasses and lead-bearing alloys, are used for metal-arc and carbon-arc welding core wire and rods. A joint AWS-ASTM specification, "Copper and Copper-Alloy Metal-Arc Welding Electrodes" (AWS Designation A5.6; ASTM Designation B225), has been established covering arc-welding electrodes for welding copper and copper alloys. Table 8 lists and gives pertinent information on the standard electrodes. Although this specification applies specifically to metal-arc electrodes, it is also generally applicable to carbon-arc filler metals. Most copper-base covered electrodes operate with d.c. reverse polarity. Some grades are also available for use with a.c.

Filler metals used in gas, carbon-arc and inert-gas metal-arc welding are often of the same composition as the base metal. At present there is no AWS-ASTM specification covering copper-base filler rods for gas, carbon-arc and inert-gas metal-arc welding, but one is now in preparation. Table 9 lists the copper and copper-alloy welding rods, along with their nominal composition and minimum mechanical properties.

Braze welding is used quite extensively on copper-base alloys. The most common braze welding filler metal, which melts below the melting point of the base metal, is the 60 copper, 40% zinc alloy. Braze welding cannot be used where color matching or high corrosion resistance is required.

Copper

The two principal kinds of copper used in welded fabrication are the oxygen bearing electrolytic tough pitch type, and the phosphorus deoxidized types.

Deoxidized Copper—Of the two, deoxidized copper is generally preferred for welded fabrication and can be welded by all of the conventional methods using filler metals as listed below. When the highest possible electrical conductivity is desired, OFHC copper (oxygen-free high conductivity copper) is used.

Metal-arc—When weld must have thermal, electrical and corrosion resistant properties comparable to those of the base metal, phosphorus deoxidized copper electrodes are used. Where service requirements permit, phosphor bronze and silicon bronze electrodes are often satisfactory. But the most common coated electrodes are the 4 to 5% tin phosphor bronze because deposit closely matches base metal in color and properties. Aluminum bronze electrodes are also sometimes used.

Carbon-arc—The filler metals used are similar to those for the metal-arc process. Bare deoxidized copper rod is used where corrosion resistance is important. Otherwise, 4 to 5% tin phosphor bronze and silicon bronze rods are used.

Gas—Deoxidized copper and silicon bronze rods are applicable. Copper rods give strengths of from 30,000 to 35,000 psi; they are too fluid to use except in downhand position and for horizontal welds in the light gages. However, by using a technique involving two torches, vertical welds in copper can be made.

Inert-Gas Metal-arc — Welds up to ½ in. can be made using bare rod of deoxidized copper alloyed with small amounts of silicon, manganese and tin; these rods are sometimes referred to as fully deoxidized. Silicon bronze rods can also be used.

Submerged-arc—Deoxidized copper with varying percentages of tin and phosphorus are used.

Electrolytic Copper—Where strong welded joints are required, electrolytic copper is not recommended because of the formation of oxides during welding that cause embrittlement at the fusion zone. For strong welds, soft

Table 8—Standard Copper and Copper Alloy Electrodes

Electrode Classifi-cation	Core Wire Material	Nominal Composition, %	Form Available	Min Mechanical Properties: Ten. Str., Psi	Yld. Str., Psi	Elong. in 2 In., %	Brinell Hardness
E Cu	Copper	99.0 Cu	Coated and bare	25,000	—	20	—
E CuSn-A	Phosphor bronze	5.0 Sn, 0.3 P max, rem. Cu	Coated and bare	40,000	20,000	15	70 to 85[1]
E CuSn-C	Phosphor bronze	8 Sn, 0.3 P max, rem. Cu	Coated and bare	45,000	25,000	12	85 to 100[1]
E CuNi	Copper-nickel	30 Ni, 70 Cu	—	45,000	25,000	25	—
E CuSi	Copper-silicon (silicon bronze)	3 Si, 94 Cu min	Coated and bare	40,000	20,000	20	80 to 100[1]
E CuAl-A	Aluminum bronze	7.5 to 9.0 Al, rem. Cu	Coated and bare	65,000	30,000	15	130 to 160[2]
E CuAl-B	Aluminum bronze	9-10 Al, rem. Cu	Coated and bare	70,000	35,000	10	160 to 210[2]
E CuAl-C	Aluminum bronze	10-11 Al, rem. Cu	Coated and bare	75,000	40,000	4	210 to 260[2]
E CuAl-D	Aluminum bronze	11-12 Al, rem. Cu	Coated and bare	65,000	45,000	—	260 to 310[2]
E CuAl-E	Aluminum bronze	12-13 Al, rem. Cu	Coated and bare	70,000	50,000	—	310 to 365[2]

[1] *500 kg load* [2] *3000 kg load*

ldering or brazing is preferred. In plications where strength is not a itical factor, electrolytic copper can e welded with the following filler etals.

Carbon-arc—Phosphor bronze rods e used for thicknesses up to ⅜ in. Velding isn't practical over this thicks because of hot shortness of weld posit. Low tin (1½ to 2%) phoshor bronze is recommended if there to be any cold working after welding. Higher tin content (8 to 10%) preferred for the heavier gages, but ill withstand only moderate cold orking.

Metal-arc—deoxidized copper, phoshor bronze (ECuSn-A), and silicon ronze electrodes are most generally ed.

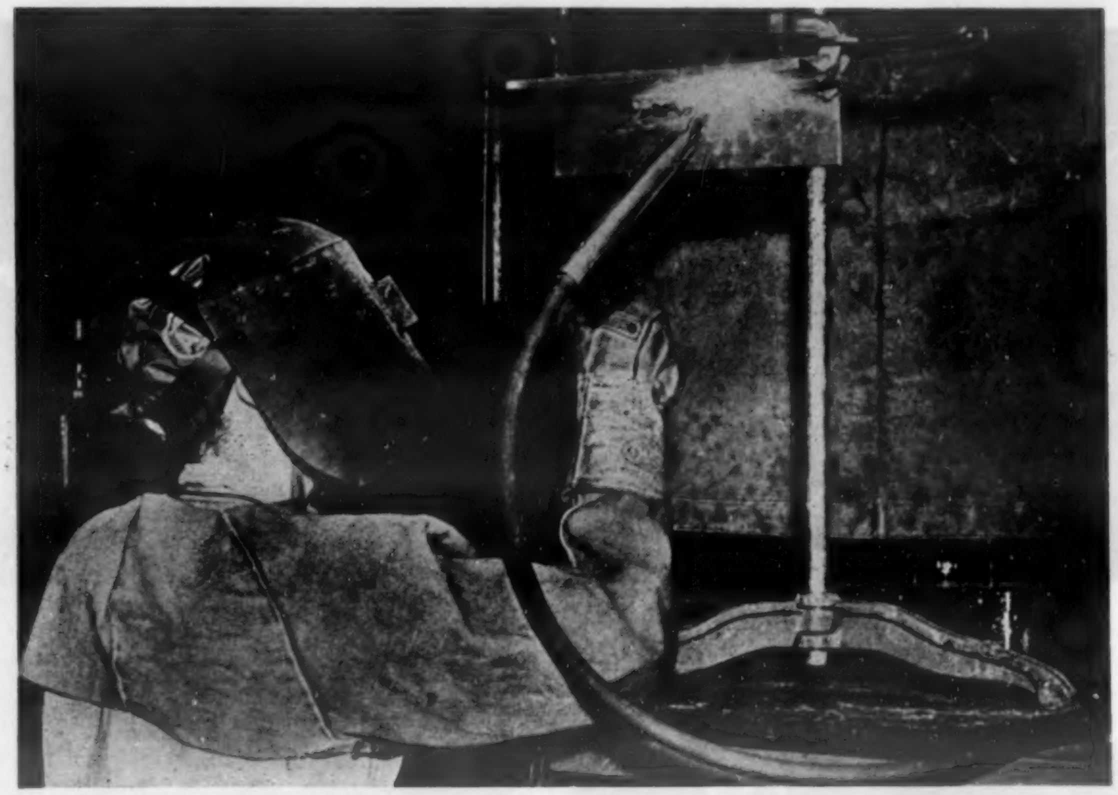
Gas—Not generally recommended. raze welding can be used with conentional brass rods and fluxes.

Submerged-arc—Used to some exnt with deoxidized copper filler metal ontaining varying percentages of tin d phosphorus.

Brasses

Copper-zinc alloys, commonly called asses, are divided into high zinc asses and low zinc brasses. The high asses, typical of which are Naval ass, Muntz metal and manganese onze, are most widely welded.

Metal-arc — Both high and low asses can be welded with 5% tin hosphor bronze (ECuSn-A) or aluinum bronze (ECuA1-A) electrodes. election depends on the service reuirements. Phosphor bronze is best r the low strength types, such as aval Brass, while aluminum bronze



In one method of inert-gas metal-arc welding, the filler metal wire also serves as the electrode for establishing the welding arc. (Courtesy Air Reduction Sales Co.)

electrodes are best for the higher strength alloys, such as manganese bronze, if comparable deposit strength is required. Aluminum bronzes provide a good color match.

Carbon-arc—Either a low fuming bronze or a silicon bronze (3% Si) electrode can be used. Silicon bronze is generally preferred because of its ease of handling during welding and greater ductility of the weld deposit. Silicon bronze is also satisfactory for the low brasses for single or multiple pass welds. Phosphor bronze (8 to 10% Sn) can be used for single pass welds, but is not suitable for applications where weld is cold worked after welding.

Gas—Low brass welding rods are not available and 1½% silicon bronze rods are considered best practice. Low brasses can be joined by braze welding using low copper-zinc rods, but they cannot be used when corrosion resistance comparable to the base metal is required. High brasses are welded using rods of the same analysis as the base metal.

Inert-Gas Metal-Arc—Silicon bronze rods are used.

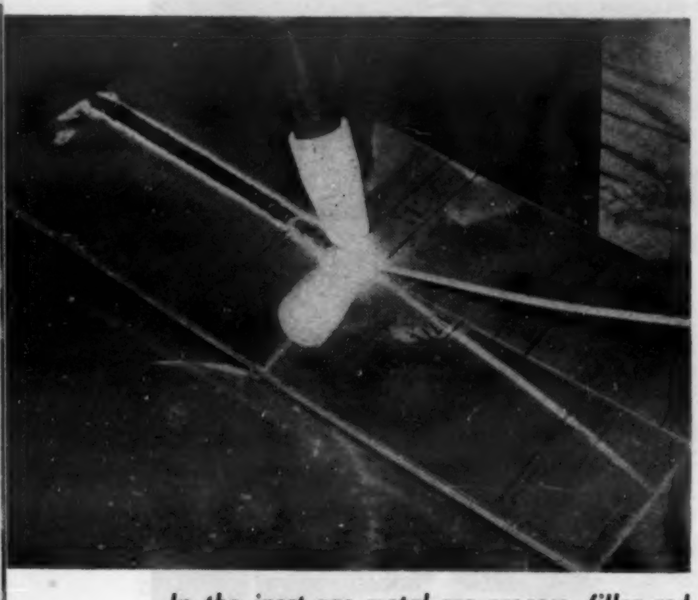
Silicon Bronze

Copper-silicon alloys can be welded by all the fusion processes. Their relatively low thermal conductivity suits

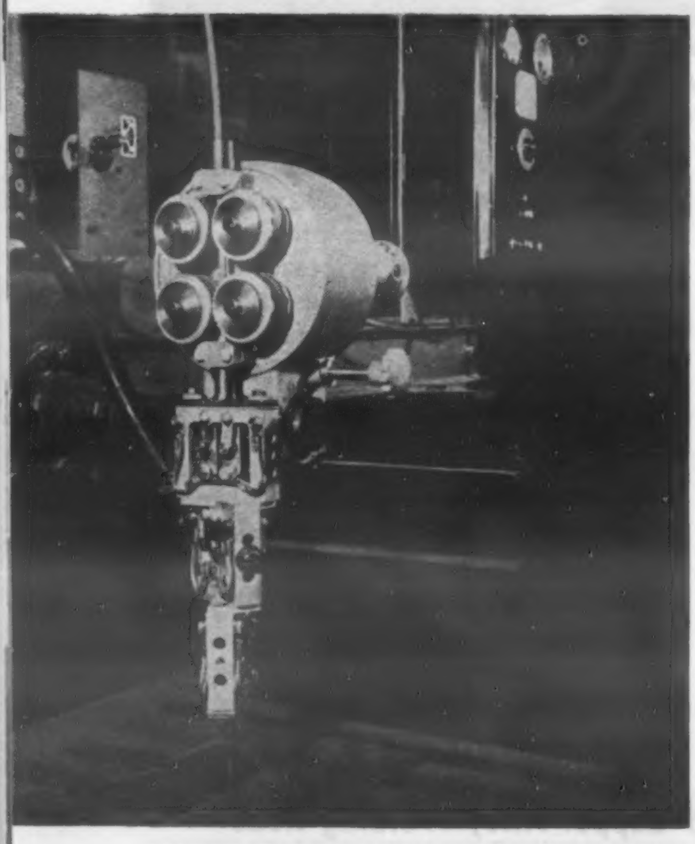
Table 9—Compositions and Mechanical Properties of Copper and Copper-Alloy Welding Rods

Common Name	AWS-ASTM Class[a]	Nominal Comp., %	Melting Point, F	Mechanical Properties: Min Tensile Strength, Psi	Min Yield Strength, Psi	Min Elong. in 2 In.	Brinell Hardness (500 Kg)
Copper	CCu	98.5 Cu	1972	25,000	7,500	20	F 25[1]
Copper-Silicon	CCuSi	94.0 Cu, 2.5-3.75 Si	1866	50,000	20,000	25	80-100
Phosphor Bronze A	CCuSn-A	93.0 Cu, 4.0-6.0 Sn	1922	40,000	20,000	15	70-85
Phosphor Bronze D	CCuSn-D	88.5 Cu, 9.5-11.5 Sn	1832	45,000	25,000	12	90-110
Copper-Nickel	CCuNi	67.0 Cu, 29.0 Ni, others, 4.0 max	2237	45,000	25,000	25	—
Naval Bronze	CCuZn-A	59.0 Cu, 39.0 Zn, 0.50-1.0 Sn	1625	50,000	20,000	25	70-90
Manganese Bronze	CCuZn-B	58.0 Cu, 38 Zn, 0-1.00 Sn	1598	55,000	22,000	20	80-100
Low-Fuming Bronze	CCuZn-C	58.0 Cu, 38 Zn, 0-1.00 Sn	1598	55,000	22,000	20	80-100
Nickel Bronze	CCuZn-D	45.0 Cu, 40.0-44.5 Zn, 9.0-11.0 Ni	1690	60,000	25,000	20	90-110

[a] Proposed; no specification issued yet.
[1] Rockwell.



In the inert-gas metal-arc process, filler rod can be fed into the welding arc separately. (Courtesy The Linde Air Products Co.)



Where high production is involved, lightly coated open-arc filler wire can be fed to the work by means of an automatic head, as shown here. (Courtesy Reid-Avery Co.)

Consideration of the type joint and positioning of the work is important when selecting weldi filler metals. (Courtesy Westinghouse Electric Corp.)

them better than other copper alloys to all-position welding, but they are hot short.

The carbon-arc method using bare silicon bronze rods has generally been considered the best procedure in the past. Phosphor bronze, grades C & D, are sometimes used for thicknesses up to 1/4 in. However, this method is rapidly being replaced by the inert-gas metal-arc process with filler metal matching the alloy. Less cracking is encountered in these hot short alloys when using this process since less heat is developed in the joint than with carbon-arc welding.

In recent years, metal-arc welding with coated silicon bronze electrodes can also be used with the metal-arc process. The weld deposits are not hot short and have higher strengths than those obtained with silicon bronze electrodes.

In welding silicon bronzes by the gas, or submerged-arc processes, filler metal of the same composition as the base metal is used.

Phosphor Bronzes

Copper-tin alloys tend to be hot short and subject to interdendritic shrinkage. Because of this, metal-arc welding, being the most rapid, is the preferred process. The two standard phosphor bronze electrodes (ECuSn-A and ECuSn-C) can be used. Bare electrodes matching the composition of base metal can also be used, although the coated electrodes are preferred.

With the carbon-arc process, phosphor bronze or silicon bronze rods can be used. Phosphor bronze is the more sluggish of the two and it more difficult to keep the weld depos free of slag inclusions. Silicon bronz is suitable for multiple pass weldin

Gas welding is generally not re ommended for phosphor bronzes. How ever, when the method must be use welding rods of Grade E (1.0 to 1.5 Sn) or Grade C (8% Sn) are recom mended. Phosphor bronzes, howeve can be braze welded using conve tional high brass rods.

Aluminum Bronze

Copper-aluminum alloys are chief welded by the carbon-arc and meta arc processes. Inert-gas-metal arc an submerged-arc methods are also used oxyacetylene gas welding is not re ommended. Covered aluminum bronz filler metals of the standard classific tions listed in Table 8 are used wi both metal-arc and carbon-arc method Bare filler metal must not be used b cause the very refractory aluminu oxides formed during welding must b

oroughly fluxed to get a satisfactory eld. However, bare rods are used ith the inert-gas metal-arc process. uminum bronze weld deposits have e highest mechanical properties of the copper alloy filler materials.

The low aluminum content elecodes, ECuA1-A and -B, are used on mmercial grades of aluminum bronze eet and plate. The higher aluminum ectrodes, ECuA1-C, -D, -E, are used join similar grades of aluminum onze, or for hard bronze overlap.

eryllium Copper

Aluminum bronze filler metal can be ed to join beryllium copper by carbon-arc and metal-arc methods. Covered rods must be used because of the highly refractory oxides formed during welding. Inert-gas-shielded-arc welding is also used successfully on beryllium copper, using bare filler rods of matching composition. Beryllium copper filler metal must be used with extreme care since the fumes from it are reported to be exceedingly toxic.

Copper-Nickel

Copper-nickel alloy sheet and plate with nickel contents from 20 to 30% can be metal-arc welded using covered electrodes having a core wire with 30 nickel and 70% copper (ECuNi). The electrodes operate on d.c. reverse polarity.

Bare rod of the same composition is used with the inert-gas-metal-arc and the submerged-arc processes. For gas welding, rods of the same composition as the base metal are used. In addition, they must contain enough manganese or silicon as deoxidizers to protect the weld metal during welding.

Nickel-Silver

Oxyacetylene braze welding is generally recommended for joining nickel silver. A high zinc bronze filler metal with around 10% nickel matches the color of nickel silver, which is white.

Table 10—Electrodes and Rods for Welding Copper-Base Alloys by Various Methods

Material	Metal-Arc	Carbon-Arc	Oxyacetylene	Inert-Gas Metal-Arc
Electrolytic Tough Pitch	Deoxidized copper Phosphor bronze Silicon bronze	Phosphor bronze	—	Deoxidized copper Silicon bronze
Deoxidized Copper	Deoxidized copper Phosphor bronze Silicon bronze	Silicon bronze Phosphor bronze Silicon bronze	Deoxidized copper Silicon copper	Deoxidized copper Silicon bronze
Low Brasses	Phosphor bronze Aluminum bronze	Silicon bronze Low fuming bronze	Silicon bronze Phosphor bronze	Silicon bronze Phosphor bronze
High Brasses	Phosphor bronze Aluminum bronze	Low fuming bronze Silicon bronze	Silicon bronze Phosphor bronze	Silicon bronze Phosphor bronze
Silicon Bronze	Silicon bronze Aluminum bronze	Silicon bronze Phosphor bronze	Silicon bronze	Silicon bronze
Phosphor Bronze	Phosphor bronze	Phosphor bronze Silicon bronze	—	Phosphor bronze
Aluminum Bronze	Aluminum bronze	Aluminum bronze	—	Aluminum bronze
Beryllium Copper	Aluminum bronze	Aluminum bronze	—	Beryllium copper
Nickel Silver	—	—	High zinc bronze	—

Filler Metals for Aluminum and Magnesium

Aluminum

Proper choice of filler metal for joining aluminum and aluminum alloys is important. Selection is usually based on such welding characteristics as the tendency to crack and fluidity, and on the corrosion resistance and/or strength requirements. On thin materials, usually less than 1/16 in., aluminum is often joined by flanging the sheet and melting this flange into the joint as the filler metal. On thicker sections filler metal in the form of electrodes or rods is generally required.

Commercially pure aluminum (2S) and 95 aluminum, 5% silicon (43S) are the two standard filler metals most commonly used for aluminum welding. The 2S alloy is used when maximum resistance to corrosion and high ductility are of prime importance. The 43S alloy is used for greater strength and to minimize the tendency for cracking. Other aluminum alloy filler metals can be employed in certain applications to provide resistance to specific chemicals, to meet special strength requirements, or to match colors on parts that are processed with subsequent oxide coatings. Such cases usually require consultation with the producer and testing of the prescribed filler metal.

Arc-Welding — Metal-arc, carbon-arc, inert-gas metal-arc, and atomic-hydrogen arc welding can be used for welding aluminum and its alloys. Shielded metal-arc welding is generally done with coated electrodes conforming to AWS-ASTM "Specifications for Aluminum and Aluminum Alloy Metal-Arc Welding Electrodes". These specifications cover two types of electrodes. Type A1-2 has a commer-

cially pure aluminum core wire giving a minimum tensile strength of deposit of 12,000 psi. Type A1-43 has a core wire containing approximately 95 aluminum and 4 to 6% silicon. Minimum tensile strength of a weld deposit is 14,000 psi. The electrode coatings must be such that they dissolve any aluminum oxide that may be formed during the welding.

The A1-43 electrode is suitable for most general purposes, and provides superior fluidity at welding temperatures. However, in applications involving special exposure or corrosion conditions it may be necessary to use a core wire of the same composition as the base metal. Electrodes for such uses are not usually stocked, and, therefore, must be ordered specially for the particular job.

The electrodes have been developed for use with direct current, preferably in the flat position, although some welding is done in the vertical position.

For carbon-arc welding the same filler metals as for metal-arc welding are used. The rods can be coated or uncoated. Improved welding speed and appearance result if the rod has a coating thinner than that on metal-arc electrodes. In automatic carbon-arc welding the filler metal and powdered flux are fed separately to the work. Commercially pure aluminum and aluminum manganese alloys are welded with 2S wire, while other alloys are welded with 43S wire.

The filler wire for inert-gas metal-arc welding is not coated because argon or helium gas envelopes the weld zone and prevents oxidation during welding. With one method the filler wire also serves as the electrode; in the tungsten-arc method the filler wire is fed into the work, just as in conventional gas welding. The filler metals are of the same composition as those described earlier for metal-arc welding. These filler metals give weld deposits having mechanical properties approximately as listed below:

Filler Metal	*TS, Psi*	*% Elong. in 2 In.*
2S	17,500	25
43S	22,000	8

Gas Welding — Commercially pure aluminum (2S) and 5% silicon-aluminum alloy (43S) are used for gas welding rods. Selection of the proper rod is important, particularly when joining alloys which have comparatively large amounts of alloying constituents. Commercially pure aluminum and aluminum of higher purity are welded with rods of the same analysis as the base metal. Type 2S rods are generally best for welding 3S alloy.

The best rod for the heat treatable alloys—53S, 61S and 63S— is 43S. Since this rod's melting point is below that of aluminum, it permits the dissipation of some of the stress set up by solidification shrinkage and thermal contraction that occurs in the weld zone as it cools. Therefore, tendency for cracking can be minimized by using the 43S rod.

Castings—For welding ordinary aluminum alloy castings, 43S filler metal or one containing 4 copper, 3% silicon is frequently used. However, if the casting is to be subsequently heat treated, filler metal of the same analysis as the base metal should be used.

Magnesium

Magnesium and magnesium alloys can be joined by gas welding and by the inert-gas-shielded arc process. In general, the filler metal for both processes should have the same composition as the alloy being joined. However, a filler metal with a lower melting point and greater freezing range than the base metal is often selected because of the better operating characteristics or to minimize the tendency for cracking. Also, slightly higher weld strengths are obtained using filler metal with higher alloy content.

Commercial filler metal rods with their respective uses are given in Table 11.

Inert-gas-shielded arc welding requires the filler metal to be of the same composition as the alloy being joined. One exception is when welding AZ31X alloy. In this case AZ61X rod which produces a stronger weld, is used to reduce cracking. Typical strength properties of welded joints in magnesium obtained using the inert-gas metal-arc process are given in Table 12.

Table 11—Welding Rods for Magnesium

Welding Rod	Nominal Comp., %	Alloys and Forms for Which Suitable			
		Sheet	Plate	Extrusion	Casting
MI	98.5 Mg, 1.5 Mn	MI	MI	MI	MI
AZ61	6.5 Al, 1.0 Zn, rem Mg	AZ31X	AZ31X	AZ31X AZ61X	—
AZ92*	9.0 Al, 2.0 Zn, rem Mg	AZ31X	—	AZ80X	AZ63 AZ92
AZ101	—	—	—	—	AZ63 AZ92

**For welding calcium-bearing AZ31 sheet where cracking is encountered.*

Table 12—Magnesium Alloys
Typical Strength Properties of Inert-Gas Metal-Arc Welds
(Butt—Joints)

Material	Form	Welding Rod	Tensile Str, Psi	Elongation in 2 In., %
MI (A)	Sheet and plate	MI	20,000	2.0
MI (H)	Sheet and plate	MI	22,000	1.5
MI	Extrusion	MI	20,000	2.0
AZ31X(A)	Sheet and plate	AZ61	36,000	12.0
AZ31X	Extrusion	AZ61	35,000	12.0
AZ61X	Extrusion	AZ61	40,000	8.0
AZ80X	Extrusion	AZ92	42,000	4.0
AZ63*	Casting	AZ63	28,000	3.0
AZ92*	Casting	AZ92	28,000	3.0

**Heat treated and aged.*

Filler Metals for Nickel and Nickel Alloys

Nickel and nickel alloy filler metals re generally selected to match the base etal being joined. Electrodes and rods re available for all the conventional elding processes. As yet no AWS-ASTM specification has been established for these materials.

Nickel

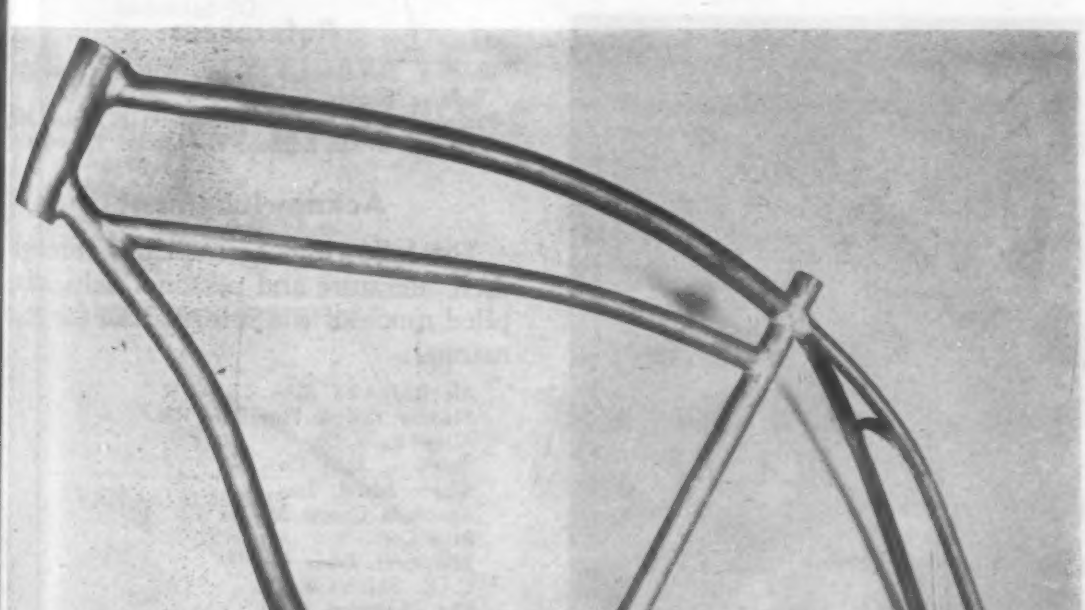
Nickel, L nickel, Duranickel, and ickel-clad steels are arc-welded with ickel electrodes. Nickel electrodes are esigned for use with d.c. reverse polarity and are suitable for all welding ositions. Nickel electrodes are unlike teel electrodes in that the molten weld metal is not as fluid and must e manipulated more carefully. Also, ickel welds have more pronounced ripples than is the case with steel electrodes.

Properly made nickel welds have mechanical properties similar to annealed nickel plate, and the weld deposit will not respond to heat treatment.

Nickel welding rods are used without flux for the oxyacetylene welding of nickel. Special nickel welding rods are available for inert-gas metal-arc welding and for atomic-hydrogen welding. For submerged-arc welding, the nickel filler wire is available in coils.

Filler metals used in submerged arc welding are in the form of bare rods or bare wire in coils. (Courtesy The Linde Air Products Co.)

To obtain sound strong welds it is essential that clean flux be used.



Most of the joints in this steel bicycle frame were braze welded with a low fuming manganese bronze wire. (Courtesy Revere Copper and Brass, Inc.)

As mentioned elsewhere in this manual, nickel core electrodes have also found quite extensive use for welding cast iron. In addition, nickel and nickel alloy electrodes are used for welding dissimilar metals combinations, such as cast iron to other ferrous metals or to nickel alloys. Such electrodes are available for use with either d.c. or a.c., and can be used in any welding position.

Monel Alloys

Monel electrodes and rods are used for joining monel, R Monel, KR Monel, and sometimes K Monel. The arc-welding electrodes can be used with d.c. reverse polarity and in all welding positions. They have a modified spray type arc with deep penetration characteristics. Monel weld deposits are somewhat harder and stronger than annealed monel base metal, but they cannot be hardened by heat treatment. Good weld contours are obtained with these electrodes.

Monel welding rods are used as the filler metal for gas, inert-gas metal-arc, submerged-arc, and atomic-hydrogen welding processes. The use of flux is

recommended for gas welding.

K Monel electrodes are available for arc welding K Monel. Their operating characteristics are similar to those of monel electrodes, but the weld deposit responds to heat treatment and, therefore, can be age hardened to give higher mechanical properties.

Inconel and Inconel X

Inconel and Inconel X can be welded with Inconel electrodes, which are designed for d.c. or a.c. and for all positions. Where an age hardenable deposit is desired, a special purpose Inconel X electrode can be used on Inconel X base metal. Electrodes of 80 nickel, 20% chromium are useful for welding the Inconel side of Inconel clad steels and for joining Inconel and Inconel X to steel.

Inconel welding rods are used for welding Inconel and Inconel X by gas, inert-gas metal-arc, submerged-arc and atomic-hydrogen methods, with one exception. Gas welding of Inconel X is not as yet recommended.

Hastelloy Alloys

The Hastelloys are welded with rods or electrodes having essentially the same composition as the base metal. Electrodes are used on d.c. reverse polarity and are suitable for all welding positions. Hastelloy welding rods are available for gas, inert-gas metal-arc, and atomic-hydrogen welding. Filler metals of Hastelloys B and C are available for submerged arc welding.

Nickel-Chromium Alloys

The 80 nickel, 20% chromium alloy and similar nickel-chromium alloys are arc-welded with 80 nickel, 20% chromium electrodes which can be used in all welding positions with d.c. or a.c. Electrodes are also available for joining other nickel-chromium compositions. In general, selection is made to match the composition of the weld deposit with that of the base material.

Coated Illium arc-welding electrodes and cast welding rods are available for joining Illium alloys.

Filler Metals for Zinc and Lead

Gas welding is most commonly used on zinc and zinc alloys. The principal requirement for obtaining a successful weld in zinc is that flux be applied on the sheet edges and on the welding rod, so that metal of the same composition as the base metal will be deposited. Thin sheets (1/32 in.) are flanged and welded without use of filler metals.

In repair welding zinc-base die castings the welding rod can be pure zinc or, preferably, a die casting alloy having a composition close to that of the casting being welded. A zinc-base rod containing approximately 4.2 aluminum, 3.0 copper and 0.05% magnesium has been used successfully in many applications and has the lowest melting temperature of any possible combination of the three major constituents.

Practically all welding of lead is done by the gas welding process. Filler metal is generally in the form of welding rods from 1/8 to 3/4 in. in dia. Final filler metal selections often depends on the user's preference; however, the welding rod should be of the same composition as the lead being joined.

Arc welding attachments to hydraulic cylinders. (Courtesy Metal & Thermit Corp.)

References

"Welding Handbook," Third Edition, American Welding Society.

"Procedure Handbook of Arc Welding Design and Practice," Ninth Edition, The Lincoln Electric Co.

Acknowledgment

The following organizations, through their literature and personal help, supplied much of the information for this manual:

Air Reduction Sales Co.
Aladdin Rod & Flux Mfg. Co.
Alloy Rods Co.
American Agile Co.
Ampco Metal, Inc.
Anaconda Copper Mining Co.
Arco Corp.
Bridgeport Brass Co.
C. E. Phillips & Co.
The Champion Rivet Co.
Chase Brass & Copper Co.
Eutectic Welding Alloys Corp.
General Electric Co.
The International Nickel Co., Inc.
The Lincoln Electric Co.
The Linde Air Products Co.
Marquette Manufacturing Co., Inc.
Metal & Thermit Corp.
National Cylinder Gas Co.
Reid-Avery Co., Inc.
Revere Copper and Brass, Inc.
Victor Equipment Co.
Westinghouse Electric Corp.

Materials & Methods

Materials Engineering File Facts

NUMBER 202
December, 1950

MATERIALS DATA SHEET

Copper-Bearing, High-Strength Wrought Aluminum Alloys

Typical Properties

Type	11S	14S[1, 2]	17S	R317	24S[1]
COMPOSITION, %					
(Excluding Impurity Limits)	Cu, 5.0-6.0 Pb, 0.2-0.6 Bi, 0.2-0.6	Cu, 3.9-5.0 Si, 0.5-1.2 Mn, 0.4-1.2 Mg, 0.2-0.8	Cu, 3.5-4.5 Mn, 0.4-1.0 Mg, 0.2-0.8	Cu, 3.5-4.5 Mn, 0.4-1.0 Mg, 0.2-0.8 Pb, 0.3-0.7 Bi, 0.3-0.7	Cu, 3.8-4.9 Mn, 0.3-0.9 Mg, 1.2-1.8
PHYSICAL PROPERTIES					
Density, Lb./Cu. In.	0.102	0.101	0.101	0.102	0.100
Melting Range, F	995-1190	950-1180	955-1185	955-1185	935-1180
Thermal Cond., Btu./Hr./Sq. Ft./Ft./F, @ 77 F (annealed)	90	111	99	99	109
Coeff. of Exp. per F:					
68 to 212 F	12.7×10^{-6}	12.8×10^{-6}	13.1×10^{-6}	12.2×10^{-6}	12.9×10^{-6}
68 to 572 F	13.5×10^{-6}	13.6×10^{-6}	13.9×10^{-6}	13.8×10^{-6}	13.7×10^{-6}
Spec. Ht., Btu./Lb./F	0.23	0.22	0.22	0.22	0.22
Elect. Res., Microhm-Cm. @ 68 F:	— 4.31 (T3)	3.45 (O) 4.31 (T6)	3.83 (O) 5.75 (T4)	— 5.75 (T4)	3.45 (O) 5.75 (T4)
MECHANICAL PROPERTIES					
Mod. of Elasticity in Tension, Psi.	10.3×10^{6}	10.7×10^{6}	10.6×10^{6}	10.5×10^{6}	10.7×10^{6}
Tensile Str., 1000 Psi.:					
Annealed (O)	—	27.0	26.0	26.0	27.0
Heat Treated (T3, T8) or (T4, T6)[3]	55.0, 59.0	62.0, 70.0	62.0 (T4)	62.0 (T4)	69.0 (T3)
Yield Str., (0.2% Offset), 1000 Psi.:					
Annealed (O)	—	14.0	10.0	10.0	11.0
Heat Treated (T3, T8) or (T4, T6)[3]	48.0, 45.0	44.0, 60.0	40.0 (T4)	40.0 (T4)	48.0 (T3)
Elongation in 2 In., %:					
Annealed (O)	—	18	22	22	22
Heat Treated (T3, T8) or (T4, T6)[3]	15, 12	20, 13	22 (T4)	22 (T4)	19 (T3)
Hardness, Bhn.:					
Annealed (O)	—	45	45	45	47
Heat Treated (T3, T8) or (T4, T6)[3]	95, 100	105, 135	105 (T4)	105 (T4)	120 (T3)
Endurance Limit, 1000 Psi.:					
Annealed (O)	—	13.0	13.0	11.0	13.0
Heat Treated (T3, T8) or (T4, T6)[3]	18.0, 18.0	20.0, 18.0	18.0 (T4)	18.0 (T4)	20.0 (T3)
Shear Str., 1000 Psi.:					
Annealed (O)	—	18.0	18.0	18.0	18.0
Heat Treated (T3, T8) or (T4, T6)[3]	32.0, 35.0	38.0, 42.0	38.0 (T4)	38.0 (T4)	41.0 (T3)
FABRICATING PROPERTIES					
Annealing Temp., F	650	650	650	650	650
Solution Temp., F	940-960	930-945	930-945	930-950	910-930
Aging Temp., F	320	340	—	—	375
Machinability[4]	A (T3, T8)	A (T6)	A (T4)	A (T4)	A (T3)
Weldability[4]: Torch	D	D	D	D	D
Inert Arc	D	C	C	C	C
Elect. Res.	D	D	D	D	D
CORROSION RESISTANCE	Compared to other aluminum alloys, this group has high resistance to rural atmospheres, fairly good resistance to industrial atmospheres, and poor resistance to marine atmospheres and sea water. These alloys are more susceptible to corrosive attack than other groups of wrought aluminum alloys. Both the degree and the nature of the attack are greatly influenced by thermal treatment. The clad sheet alloys generally have high corrosion resistance.				
AVAILABLE FORMS	Rod, hexagon bar, wire.	Extruded shapes, rolled shapes, forgings, rod, bar.	Rod, bar, wire, rolled shapes.	Wire, rod, bar, forgings.	Sheet, plate, rod, bar, tubing, wire, rivets, extruded shapes.
TYPICAL USES	Screw machine products.	Heavy duty forgings; power shovel bails; airplane fittings; structural members.	Structural applications in construction and transportation; screw machine products.		High-strength structural members; rivets; screw machine products.

NOTES: [1] *24S also available as sheet and plate clad with aluminum of 99.3% min. purity. 14S available clad with 53S.*
[2] *Similar to 14S is Hardclad 301. Core: 4.0 to 5.0 Cu, 0.75 to 1.2 Si, 0.70 to 1.0 Mn, 0.25 to 0.55 Mg. Claddings: 0.50 to 0.90 Si, 0.25 to 0.75 Mn, 0.80 to 1.2 Mg.*
[3] *(T3, T8) for 11S. (T4, T6) for 14S. T3—Solution treated, then cold worked. T8—Solution treated, cold worked, then aged. T4—Solution treated. T6—Solution treated, then aged.*
[4] *Letter A indicates most favorable property, B less favorable, etc. Relative to aluminum alloys only.*

Prepared with the assistance of Aluminum Co. of America and Reynolds Metals Co.

Materials & Methods

Materials Engineering File Facts

NUMBER 203
December, 1950

MATERIALS:
Carbides

Recommended Carbide Grades for Various Applications

This chart presents the manufacturer's recommendations for carbides for the uses indicated, and it is not intended as a grade comparison chart. It is not an endorsement of any manufacturer's product, nor is it an approved list of sources.

	Application	Designation	Adamas	Carboloy	Carmet	Firthite	Kennametal	Talide	Vascoloy Ramet	Wesson	Willey
CHIP REMOVAL											
Cast Iron, Nonferrous and Nonmetallic Materials	Roughing Cuts—Cast Iron and Nonferrous Materials	C-1	B	44A	CA3	H	K6	C89	2A68	GS	E8
	General Purpose—Cast Iron and Nonferrous Materials	C-2	A	883	CA4	HA	K6	C91	2A5-2A8	GI	E6
	Light Finishing—Cast Iron and Nonferrous Materials	C-3	AA	905	CA7	HF	K8	C93	2A7	GA	E5
	Precision Boring—Cast Iron and Nonferrous Materials	C-4	AA	999	CA8	HF	K8	C93	2A7	GF	E3
Steel and Steel Alloys	Roughing Cuts—Steel	C-5	DD	78C	CA5	T-04, T-89	K2S	S88	EE	WS	945
	General Purpose—Steel	C-6	D	78B	CA1	TA, T-89	K2S	S90	EM	WM	710
	Finishing Cuts—Steel	C-7	C	78	CA2	T-16	K3H	S92	E	WH	606
	Precision Boring—Steel	C-8	CC	831	CA6	T-31	K5H	S92	EH	WH	509
WEAR APPLICATIONS											
	Wear Surface—No Shock	C-9	A	883	CA4	HA	K8	C89	2A68 1WR	GI	E8
	Wear Surface—Light Shock	C-10	B	44A	CA3	H	K6	C88	2A3 2WR	GS	E12
	Wear Surface—Heavy Shock	C-11	HD-20	55B	CA10	HC	K1	C8515	2A16 3WR	M	E18
IMPACT APPLICATIONS											
	Impact—Light	C-12	RDB	55A	CA10	DC-1 DC-2	K1	C8515	2A3 AW	GS	E12
	Impact—Medium	C-13	HD-20	55B	CA11	DCX DC-3	K18	C8020	2A16 AX	M	E18
	Impact—Heavy	C-14	HD-25	190	CA20	DC-4	K25	C7525	2A20 AX AY	M	E25

Courtesy Adamas Carbide Corp.

New Materials and Equipment

Materials

Phenolic Laminate

Offering an unusual combination of properties for use in high-frequency insulating applications, a new paper-base phenolic laminate has been developed by *The Richardson Co.*, Melrose Park, Ill.

Called Insurok Grade T-812, the new electrical laminate is said to have a desirable balance of electrical and physical properties. These include outstanding electrical characteristics, high physical strength, excellent punchability, low moisture absorption and high insulation resistance—1,000,000 megohms after humidity conditioning (1/16-in. sheet).

Because of its excellent electrical properties, even after exposure to humidity, Insurok Grade T-812 is expected to find wide use in the radio and television industries.

Multiple-Alloy Plate Steel

Combining high strength with excellent ductility and toughness, even at sub-zero temperatures, a new multiple-alloy plate steel developed by *Carnegie-Illinois Steel Corp.* is said to be suitable for applications where high strength and good weldability are required.

Heat treated to a minimum yield strength of 100,000 psi with almost double the strength of high-strength, low alloy steels and almost triple that of ordinary welding grade structural steels, Carilloy T1 is said to effect considerable savings in applications calling for heavy steel members of ½-in. thickness and up.

Welding does not adversely affect the properties of this steel, according to the manufacturer, and no special preheating or postheating treatments are required in welding or gas-cutting operations beyond those used with ordinary structural steels. If low-hydrogen type electrodes are used in the operation, the steel is not susceptible to under-bead cracking.

Fabricating of the new material requires no special equipment or procedures. Bending or forming can be accomplished cold if sufficient power is available to overcome the steel's high yield strength.

The unique properties of this new steel are obtained by blending multiple alloying elements, coupled with precision heat treatment, while carbon content is held to at 0.18 max to promote ease of welding and gas cutting.

Further information on the new multiple-alloy plate steel can be obtained from United States Steel Corp. Subsidiaries, 429 Fourth Ave., Pittsburgh 19.

Silicone Rubber Compound

A new silicone rubber compound, which is said to permit rubber fabricators to mold silicone rubber parts with greater ease and improved mechanical and thermal properties, has been announced by the Chemical Dept. of *General Electric Corp.*, Pittsfield, Mass.

Designated as 81223 compound, the new rubber is outstanding for its ease in processing. According to the manufacturer many parts can be fabricated from it without prolonged oven cure and, after only a 5-min warm-up, it has excellent molding and extrusion properties. Because of the compound's outstanding hot tear strength, parts with undercuts can be easily removed from molds. Neutral in color, the stock can be colored for product identification purposes for individual fabricators.

Many new applications for silicone rubber mechanical goods, such as boots, sleeves, belting, hose and mountings, are anticipated.

CONTENTS

Laminated Metal

An improved composite metal has been announced by the *General Plate Div.* of *Metals & Controls Corp.*, Attleboro, Mass.

Called Alcuplate, it consists of aluminum and electrolytic copper, the two layers bound together by a solid phase bonding process which assures the absence of objectionable voids, oxides, and compound inclusions.

Since there is nothing between the aluminum and copper to offer any resistance to current or heat, the metal is said to be an excellent conductor of electricity and heat, parallel or perpendicular to the surface. Practical applications for this metal have been found in the electrical field for clips, shims, bushings and terminals. These parts are reported to have solved many of the problems encountered in termination of aluminum conductors, as the aluminum side of such a part provides the ideal aluminum-to-aluminum connection. Similarly, Alcuplate tubing can be used in joining aluminum tubing to copper tubing.

Parts & Forms

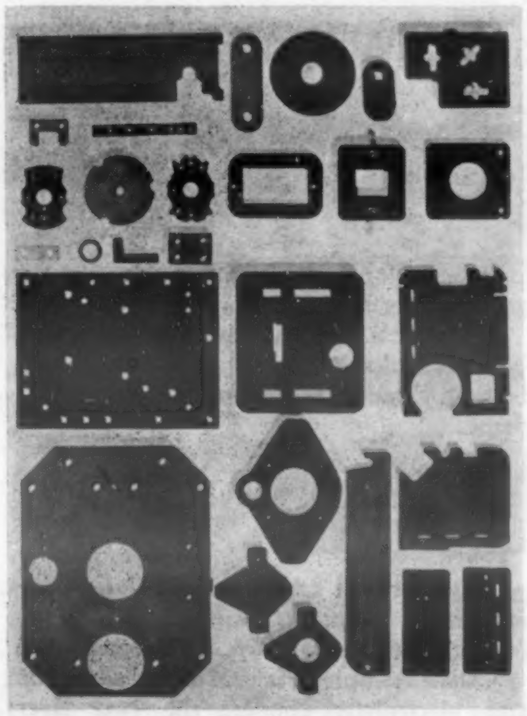
Nonmetallic Stampings

Short-run stampings of phenolic resins, vulcanized fibers, plastics, insulation paper, and other nonmetallic materials are currently being offered by *Federal Tool and*

New Materials and Equipment
(CONTINUED)

Manufacturing Co., 3600 Alabama Ave., St. Louis Park, Minneapolis, Minn.

Stampings for radios or electric frames, insulators, spacers, panels, gaskets and cams



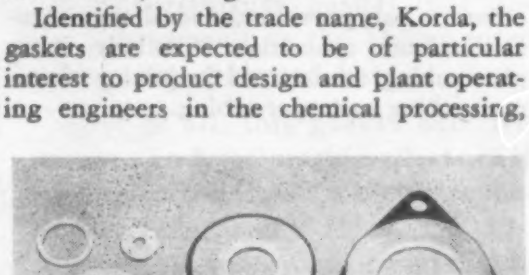
Phenolic stampings, or other special stamping services, can be obtained in any quantities from three pieces to 2,000.

are made to specifications in any dimensions up to 9 by 12 by 1/8 in. thick. Stampings can be obtained in any quantities from three pieces to 2,000.

Teflon Gaskets

An extensive new line of gaskets fabricated from Teflon is now being manufactured by *Chicago Gasket Co.,* 1275 W. North Ave., Chicago 22.

Identified by the trade name, Korda, the gaskets are expected to be of particular interest to product design and plant operating engineers in the chemical processing,



These Teflon products include (left to right) three solid Teflon gaskets, a Korda-clad ring gasket, and a Korda-clad gasket for use with Corning Pyrex glass piping.

food, pharmaceutical, leather, paper, paint and petroleum industries.

A heavy duty plastic, Teflon is said to have excellent heat resistance and to be unaffected by all except molten sodium and fluorine at elevated temperatures and pressures.

For industrial uses, Teflon is produced in many different forms, including both solid and Teflon-jacketed gaskets. Available in hard, medium and soft grades, the gaskets are suitable for all metal and nonmetallic flanges, and are produced in all sizes from 1/2 in. to 6 in. i.d. inclusive for ASA or special flanges.

Television Deflector Yoke Core

High-permeability cores for deflection of wide-angle, large-screen, television picture tubes are now available from *Westinghouse Electric Corp.,* P.O. Box 2099, Pittsburgh 30, Pa.

Made of Hipersil, a cold-rolled, grain oriented electrical steel, the cores are said to have exceptionally low reluctance at all flux densities. Wound and bonded in circular form from a continuous strip of 5-mil material, the cores are then cut accurately into two "C" shaped pieces for ease of assembly around deflection coils. The thin laminations, plus superior magnetic characteristics of the steel, are said to result in excellent linearity and sharper pictures.

Another feature of the cores is that they are rugged and completely free from magnetic instability due to change in temperature.

Coatings & Finishes

Colloidal Graphite Dispersion

A colloidal graphite coating known as "Dag" Dispersion #154 is now being manufactured by *Acheson Colloids Corp.,* Port Huron, Mich.

The product is currently being used by Raytheon Manufacturing Co., Newton, Mass., as an outside coating of their CK1026 radiation counter tubes because it is chemically inert, electrically conductive, opaque, and adheres to any glass surface despite surface scratching.

According to Raytheon's engineering department, "Dag" Dispersion #154 produces a durable coating on the outside of the tube and performs the function of a mechanical contact, permitting a clip to be snapped on the tube without danger of scratching the surface. The coating is also said to be a collector of ion current.

In the past, a problem existed in obtaining an external coating which would be a good conductor, give good appearance, ad-

New Geiger Counter tubes are externally coated with "Dag" Dispersion #154.

here to glass, and not scratch off. Use of a mixture of "Dag" and hydrolyzed ethyl silicate, however, is said to have provided the answer.

Multi-Colored Enamel

New MultaColor enamel, designed to provide a finish of two or more colors in one operation, is now being manufactured by *United Lacquer Manufacturing Corp.,* 101 W. Elizabeth Ave., Linden N. J.

When applied to any surface by the dip or spray method, the enamel is said to provide a uniformly distributed broken-effect finish of two or more colors which can be air- or oven-dried.

Put through a series of tests, MultaColor is reported to have given excellent results on every type of surface, including wood, metal, paper, fibre, plaster-of-Paris, celotex, masonite and gypsum.

MultaColor is available in 16 color combinations, and can be prepared in a large variety of others.

Cleaning & Finishing

Deburring Method

A new method for deburring gears and similar shaped parts has been developed by *The Osborn Manufacturing Co.,* Cleveland.

Ten times the amount of work previously turned out by hand is said to be processed by this method, which uses a semi-automatic universal work piece holder and brushing lathe set-up. In operation, the worker places the gear on the holder which,

New Materials and Equipment

in turn, presents the gear to the brush. Automatic pre-set timers determine the length of brushing each gear receives.

Adaptable to many practical sizes of brushes, the new Osborn brushing lathe can be used on a wide range of gear sizes.

Abrasive Stones

Availability of a specially engineered line of silicon carbide and aluminum oxide abrasive stones has been announced by the *Industrial Products Div., Elgin National Watch Co.*, Elgin, Ill.

An outstanding feature of the line is said to be color identification for instant selection of the proper stone. Each stone is permanently color tipped in a brilliant range from black to yellow according to its grit size. Hardness and cutting characteristics are precisely controlled.

Sold under the trade name Elgin Dymo, the stones range in size from 1/8 in. by 4 in. to 1 in. by 6 in., from 220 grit to 600 grit, and from extra soft to medium hard. They are available in rectangular, square, triangular, half-round and round shapes.

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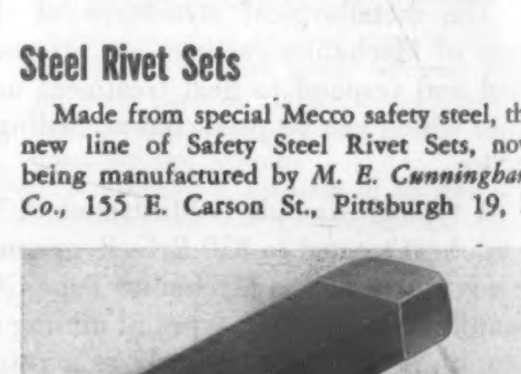
Welding & Joining

Steel Rivet Sets

Made from special Mecco safety steel, the new line of Safety Steel Rivet Sets, now being manufactured by *M. E. Cunningham Co.*, 155 E. Carson St., Pittsburgh 19, is



These new rivet sets are stocked in five standard sizes for 1/8- to 9/32-in. rivets.

designed to prevent spalling, mushrooming and injury to personnel.

According to the manufacturer, the Safety Steel Rivet Sets give considerably more service even on the most difficult production jobs, saving both time and costs.

Two shank designs are available: the

Coddled
CASTINGS

Like a doting parent — each Sivyer craftsman takes pride in the birth and growth of a casting. From molten metal to finished product, each casting is anxiously watched, inspected, x-rayed, calipered, and educated to its pattern destiny by scientist and engineer alike. This "coddling" might spoil a child, but in a casting it is your best assurance of accuracy, long life and trouble-free performance. (Have a cigar?)

how to identify better steel castings

"Good breeding tells", says the old axiom. We believe it's particularly true of castings. So look for the Sivyer ⟨S⟩ . . . your guarantee of better high alloy and specification steel castings.

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SPECIALISTS IN HIGH ALLOY AND SPECIFICATION STEEL CASTINGS

SIVYER STEEL CASTING COMPANY • MILWAUKEE ⟨S⟩ CHICAGO ⟨S⟩

New Materials and Equipment

patented Cunningham Wedge Grip design, providing knurled grip, and the standard straight shank design.

Band Saw Blade Welder

Now available from *Brennan Manufacturing Co.,* 228 Seeley St., Brooklyn, N. Y., a new portable, low cost band saw blade welder is able to handle the new 0.050-in.

Housed in a welded steel case, this new welder's overall dimensions are a handy 7¾ by 12 by 7 in.

dia contour-cutting band saw blade as well as all types of blades up to ½ in. flat.

Advantages claimed for the welder include a built-in grinder, designed to remove flash from the weld; simplified controls, said to assure uniform results at all times; no tension or adjustment or knobs to turn; and a gage for checking thickness of weld on flat saws.

Forming & Machining

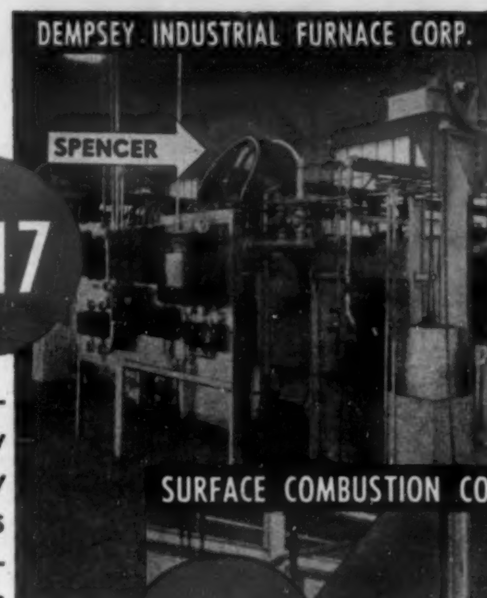
Rotary Tablet Presses

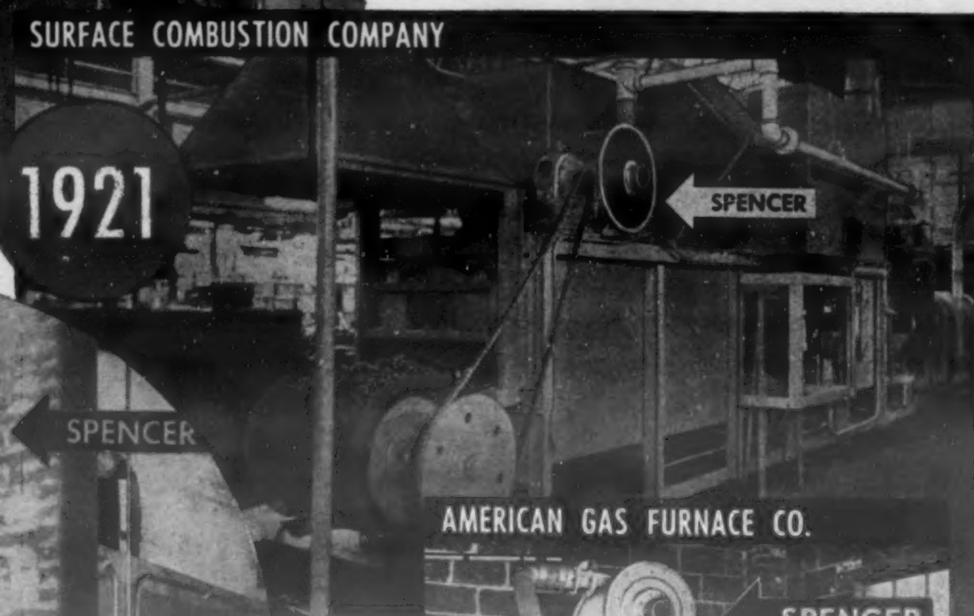
Arthur Colton Co., Div. of Snyder Tool and Engineering Co., 3400 E. Lafayette Ave., Detroit 7, has announced the development of two high-speed rotary tablet presses

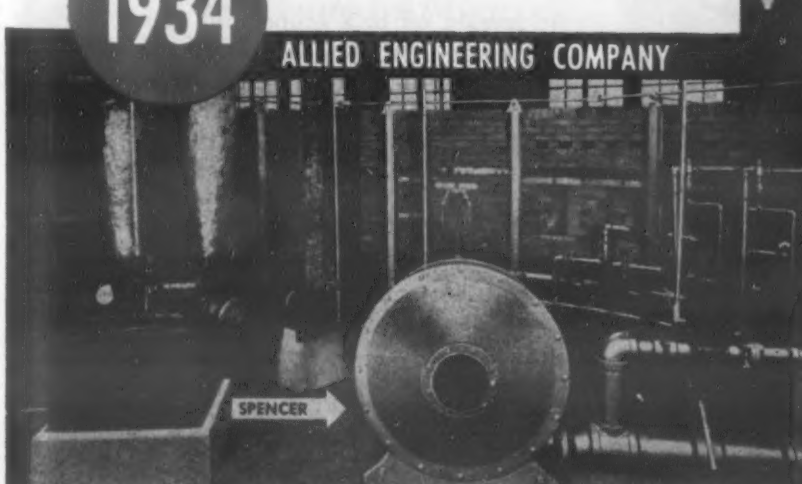
Since 1917

The first Spencer Turbo was installed in 1917. Many of the early machines are still in service. A few of the equipment manufacturers that have used Spencers consistently (see dates) for many years are represented on this page.

SPENCER TURBO COMPRESSORS







359-F

THE SPENCER TURBINE COMPANY • HARTFORD 6, CONNECTICUT

SPENCER
HARTFORD

New Materials and Equipment

for the production of a wide range of tablet sizes and plastic preforms.

One unit is the Colton No. 227 double rotary tablet press, which has a maximum production capacity of 1575 tablets per min, maximum tablet dia capacity of ½ in., and a maximum cell depth of ¾ in. The press, containing 27 punches and dies and two stamping stations, is said to exert a maximum pressure of 5,000 lb.

In operation, the dies are overfilled and

This Colton high-speed rotary tablet press is designed to produce a wide range of tablet sizes and plastic preforms.

leveled off to a proper cell depth. Variable speed drive permits operating speeds to be adjusted to suit different types of tablet material, while power is transmitted to the head through a twin disk clutch.

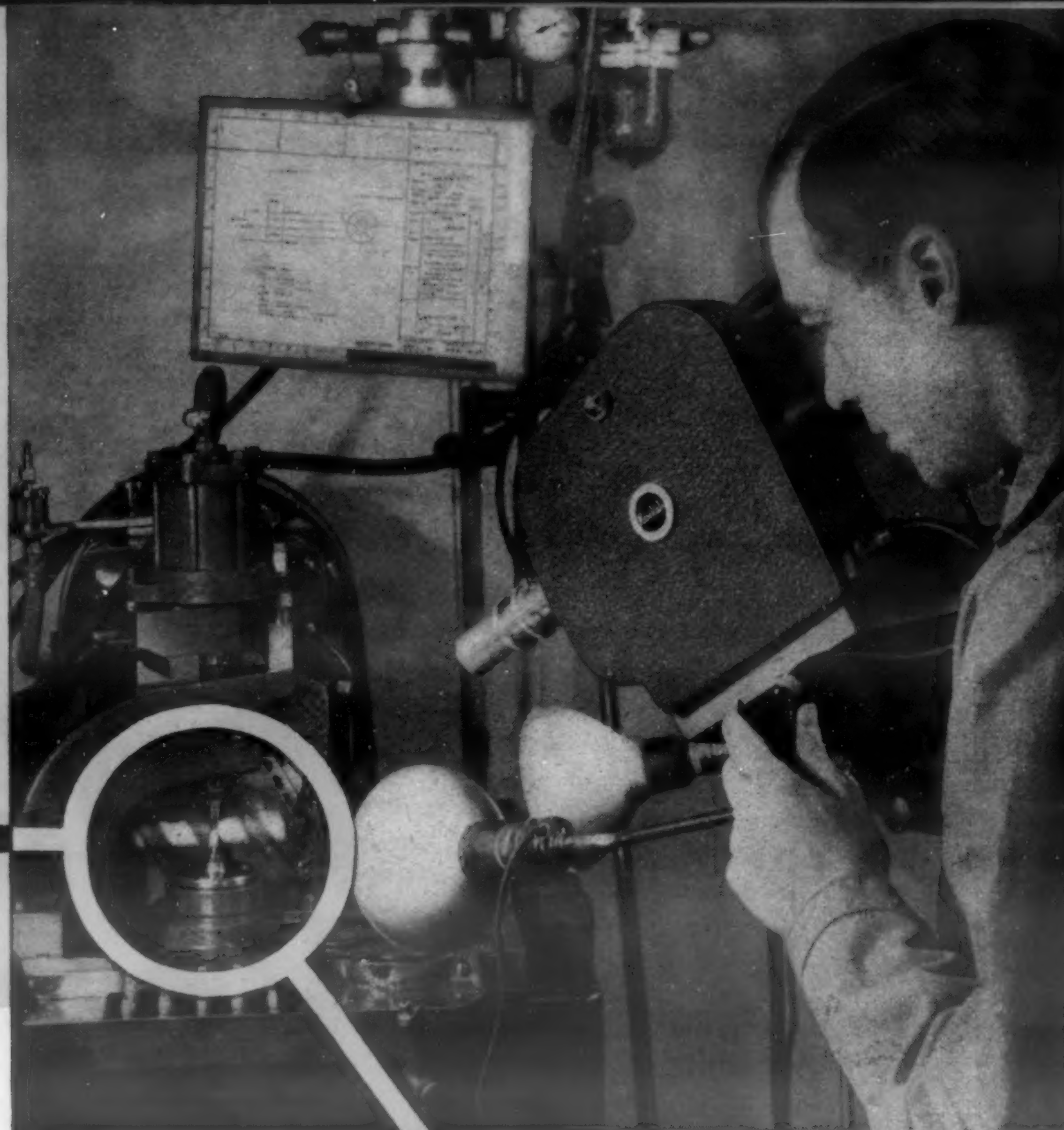
The second unit is the Colton No. 233 double rotary tablet press which has a maximum output of 1930 tablets per min, with a maximum tablet dia of ¾ in. It has 33 punches and dies, but in all other details is said to resemble the No. 227.

Powder Metal Press

The new Stokes S-5 40-ton powder metal press, a cam-operated unit for the production of electric motor, radio and television parts, cemented carbides, porous bearings, and other powder metal pieces, is now being manufactured by *F. J. Stokes Machine Co.*, 5900 Tabor Rd., Philadelphia 20.

New design is said to largely eliminate the necessity for changing cam inserts, while changes in set-up are accomplished in a fraction of the time previously required. The press can be used for sizing and coining as well as for forming through the use

The shortest distance between guessing and knowing



Fast-moving machines are hard to study under actual working conditions. But with high speed movies you can slow down fast action to a pace the eye can follow.

With the Kodak High Speed Camera you can take pictures of your problem (up to 3200 a second on regular 16mm movie film). Then you can see the operation clearly—enlarged on the projection screen—slowed down 200 times! You can *see* the reasons for excessive wear, faulty operation, noise, vibration, or early failure. What you see can point the way to better design, better methods, better performance.

High speed photography is not difficult, and its cost is small compared with the savings it makes possible. For more information, write for the booklet "Magnifying Time" or for loan of the 16mm demonstration film made with the Kodak High Speed Camera.

EASTMAN KODAK COMPANY, Industrial Photographic Division, Rochester 4, N. Y.

High-Speed Movies

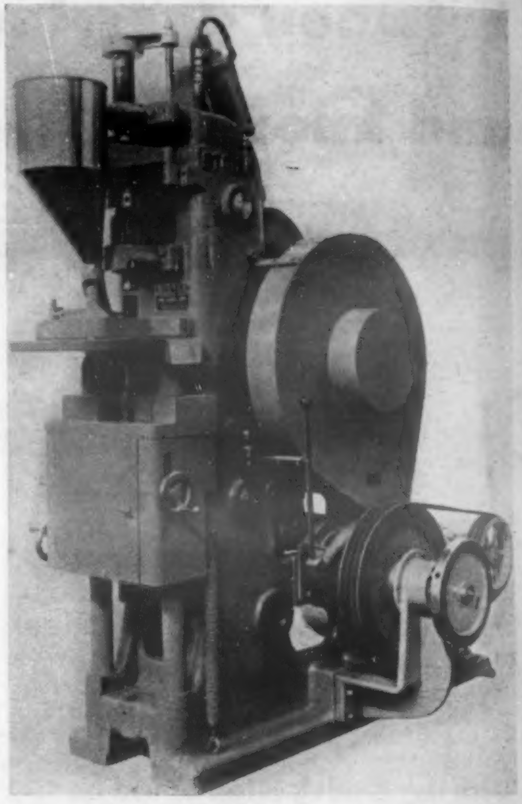
. . . another important function of photography

Kodak
TRADE-MARK

New Materials and Equipment

of a special attachment. When used as a sizing press, the parts can be fed either by hand or automatically at full speed.

Thin sections that are difficult to fill, such as thin-walled bushings, are greatly speeded up in production by the use of an



Necessity for changing cam inserts is largely eliminated through use of the Stokes S-5 powder metal press.

agitated feed shoe, which also improves the uniformity of fill when working with materials containing cotton flock or asbestos fiber filler, which do not feed easily.

Grinding and Lapping Machine

A new model bench grinding and lapping machine which enables the use of silicon carbide abrasive wheels as well as diamond wheels is being manufactured by *Wickman Manufacturing Co.*, 15533 Woodrow Wilson Ave., Detroit 3.

An improvement over the former Model

A milled slot on the table of this grinding and lapping machine permits use of a protractor for angular grinding.

New Materials and Equipment

GF-2, this grinder includes a second wheel guard for use with ordinary abrasive wheels, a 3-position table to provide for wheel wear, a milled protractor slot, and a new coolant filter.

The wide wheel guard is fitted with splash protectors on each side for effective control, while the table can be set in three positions relative to the grinding wheel face, thus allowing compensation for wheel wear.

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Testing & Control

Vibration Tester

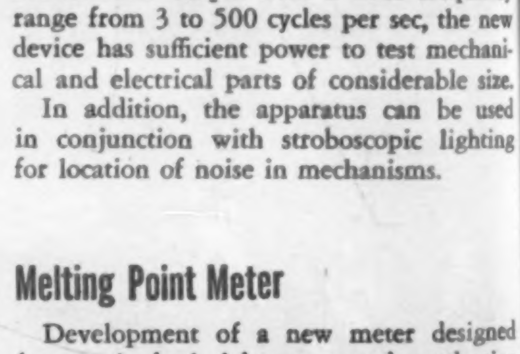
Designed for use by manufacturers who are interested in subjecting their products to vibration tests, the Model S-3 vibration exciter is now available from *M. B. Manufacturing Co.*, New Haven 11, Conn.

The exciter is said to be able to shake out the trouble spots in machinery by finding resonances excited by vibration forces during operation. With an upper limit of 200-lb force output over a wide frequency range from 3 to 500 cycles per sec, the new device has sufficient power to test mechanical and electrical parts of considerable size.

In addition, the apparatus can be used in conjunction with stroboscopic lighting for location of noise in mechanisms.

Melting Point Meter

Development of a new meter designed for use in both laboratory and production to determine the melting points between 20 and 500 F of waxes, resins, gums, fats, tars, plastics, low melting alloys, and organic and inorganic compounds has been announced



The Model Clarkstan Melting Point Meter is designed to determine melting points between 20 and 500 F of various metals.

by *Clarkstan Corp.*, 11921 W. Pico Blvd., Los Angeles 64.

In the operation of the Model 304 Clarkstan Melting Point Meter, a small quantity

New Materials and Equipment

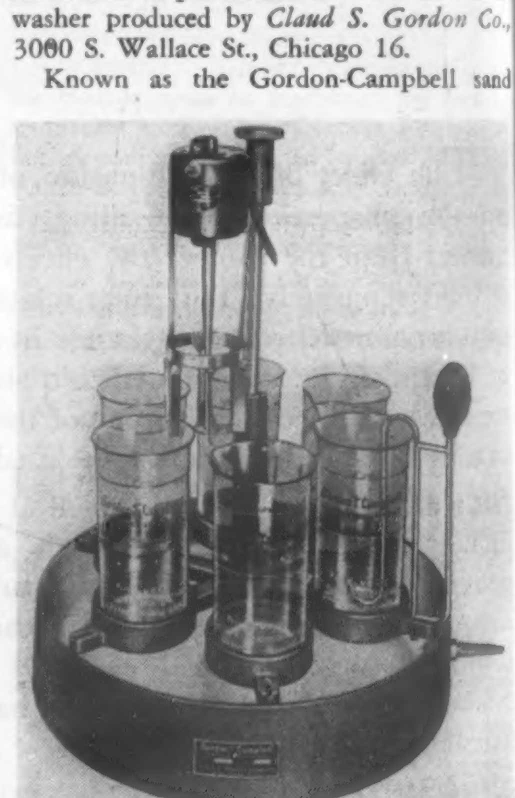
of the substance is placed on a chromium plated platen or bar, electrically heated so that a temperature gradient is held along its length. A small thermocouple junction is placed at the point where the demarcation between the molten and solid particles is observed, and within a few seconds the meter indicates the temperature of the point chosen. A screw feed enables the operator to follow the melting point as the bar temperature changes.

Both platen and thermocouple are said to be easily removed for cleaning or change, and the platen can be used on any one of its four sides. The meter operates on 100 v., a.c. or d.c.

Sand Washer

All of the various steps required by the American Foundrymen's Society for the determination of the clay content of foundry sands can be performed with the new sand washer produced by *Claud S. Gordon Co.*, 3000 S. Wallace St., Chicago 16.

Known as the Gordon-Campbell sand



This Gordon-Campbell sand washer simplifies the determination of clay content of foundry sands.

washer, this device employs a centrifugal unit to remove the clay from the sand grains. A single-blade impeller driven at high speed by an electric motor throws the sand grains against baffles suspended in the beaker containing sand and water.

The new sand washer is available in two models—a single-unit washer with one graduated Pyrex beaker and a 6-unit washer with six beakers. Either model, complete with syphon assembly and stand, is said to

New Materials and Equipment

be suitable for any other of the wide variety of similar washing operations generally employed in testing laboratories.

Utility Mixer

A new utility mixer for investigating and testing molding and core sand mixtures or for the preparation of laboratory samples is being manufactured by *Claud S. Gordon Co.*, 3000 S. Wallace St., Chicago 16. Chief

Molding and core sand mixtures can be tested and laboratory samples prepared in the Gordon Campbell utility mixer.

advantages of the Gordon-Campbell utility mixer are said to be its durability, simplicity of construction and operation, ease of cleaning, and large capacity.

The mixer is hand operated and has a stainless steel mixing bowl 12 in. in dia. and 5½ in. high and a mixing unit, which consists of a revolving arm with a scraper at one end for removing the material from the wall of the bowl. At the other end of the pinion is a mixing paddle that rotates on its own axis as it travels around the bowl.

•

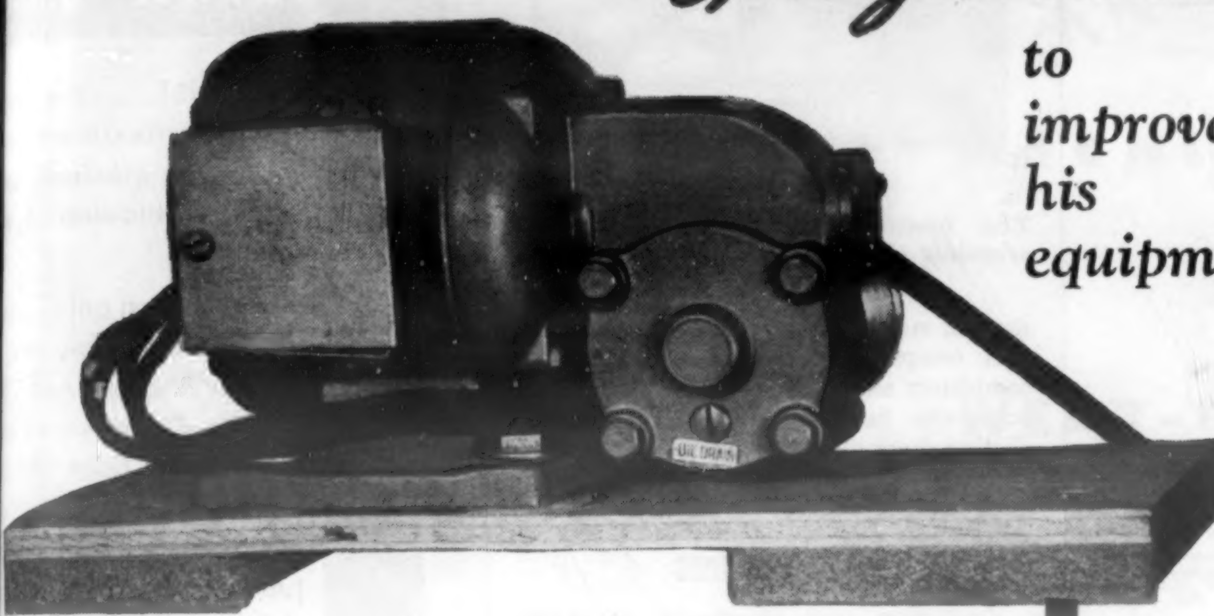
Heating, Heat Treatment

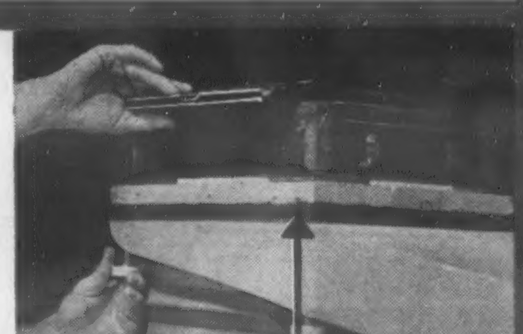
Horizontal Furnace

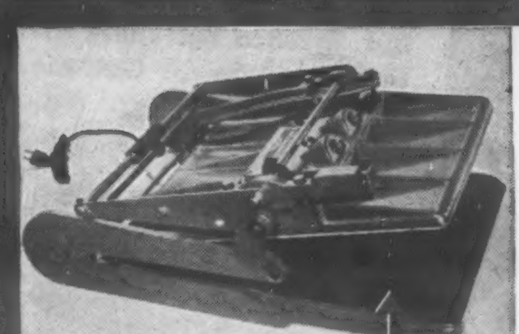
Now in production by *United States Radiator Corp.*, 300 Buhl Bldg., Detroit 26, is a new horizontal warm air furnace.

With a scientifically designed combustion chamber and burner, coupled with high quality gas controls, the furnace is said to yield fuel efficiency never before attained in a model of this type.

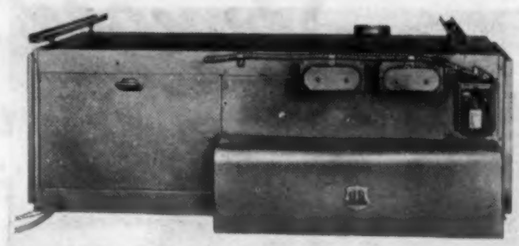
Made in three gas-fired models rated at 60,000, 80,000 and 100,000 Btu input, respectively, the furnace can be used with







New Materials and Equipment



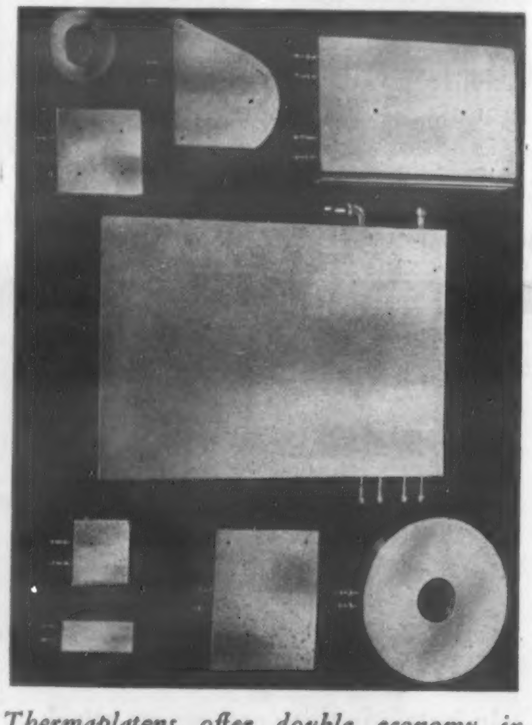
This horizontal type furnace is readily adaptable to almost any installation condition or space requirement.

natural, manufactured, or L.P. gaseous fuels.
A compact package unit, it is shipped completely assembled with all controls and accessories fully mounted and wired, including thermostat and thermostat wires.

Electrically Heated Platens

Production runs or special out-of-the-ordinary applications for domestic, commercial and industrial requirements for electrically heated platens have been solved, according to *Thermel, Inc.*, 3340 W. Lake St., Chicago 23, with their product Thermaplatens.

The platens, now being used for die heating, compression molding, plasticizing, heat sealing, branding and vulcanizing, are said



Thermaplatens offer double economy in both low and high wattage application, in addition to correctly applied spot heat.

to assure uniform heat and long life, in addition to offering economy.

Available in aluminum for temperatures to 750 F, and in aluminum bronze, brass, gray iron, copper, Meehanite and other metals for elevated temperatures, these platens can be provided with cooling coils for faster production cycles.

New Materials and Equipment

General

Conveyor Unit

Construction of a new conveyor u "Chip-Tote", designed to remove me chips or turnings while automatic machin are in operation, has been announced

Completely self-contained, the new "Ch Tote" can be made available to meet heig and width requirements of all me removing machine tools.

May-Fran Engineering, Inc., 1703 Cla stone Rd., Cleveland 12.

In operation, chips are funneled into t unit's conveyor belt by means of a st hopper, and then transported along the co veyor's incline for discharge into tote bo or on to a carry-off conveyor system.

"Chip-Tote" is said to handle hot, heav and wet or dry chips and turnings fro production machines of all standard mak

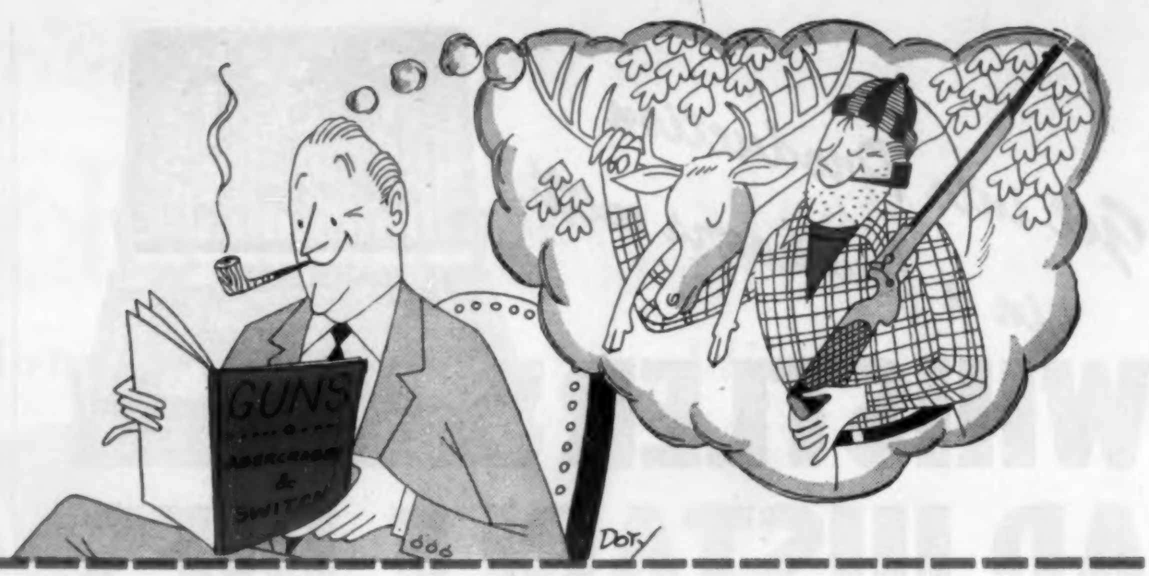
Steel Marking Process

A new method of applying permane markings and designs on stainless steel h been developed by *Stainless Ornamenta Inc.,* 12 Harcourt St., Boston.

In the process, called Ateen-Ate, blac ened stainless steel is treated to produ permanent black designs or markings contrast to the lustrous surface of stainle Blackened areas are actually part of th stainless steel surface, and are said to hav anti-corrosive qualities equal to stainle steel.

Important applications include placi easily read markings on dials, signs, na plates and instruments and, since the pro ess will handle up to 132-screen halfton reproducing photographs on stainless ste

The time to sell a man a gun is when he's concentrating on hunting!



The time and place to sell materials, parts and finishes is in

Materials & Methods

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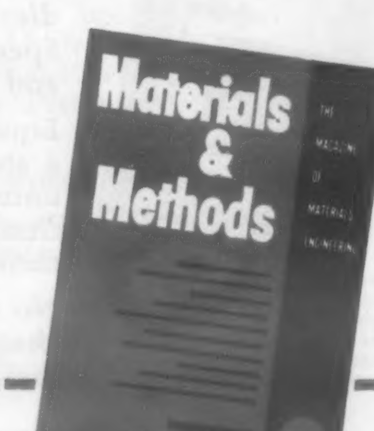
- Hardware, cutlery and tools
- Building equipment and products
- Process industries equipment
- Ordnance
- Ships, boats, marine equipment
- Containers
- Fine metalware, jewelry and novelties



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News Digest

ASM Papers . . .

continued from pag

At 1200 F, yield strengths var from 3700 to 6700 psi, tens strength from 12,000 to 23,000 and elongation from 81 to 51% f alloys ranging in iron content fro 0.45 to 5.16%.

The authors found that alloys co taining up to 7% iron can be work at 1560 F when protected from ox dation. Alloys containing as much 4.4% iron can be reduced 60% cold working. Heat resistance and strength data indicate the alloys w be restricted to uses below 1020

Titanium-Chromium Alloys

"Preparation and Properties of T tanium-Chromium Binary Alloys" w discussed by D. J. McPherson, A mour Research Foundation, and M. G Fontana, Ohio State University. Th choice of chromium as an alloyi element with titanium was based o the known value of this metal stainless steels and in most heat re sisting alloys.

Forgeable range in the titaniu chromium system was found to be th titanium-rich alloys containing 0 20% chromium. These alloys ha high room-temperature strength com bined with low specific gravity. Te sile strength of titanium was near doubled by additions of 13 to 18 chromium, with little loss of ductil and only slight increase in weig

The authors found that chromiu additions up to 16% chromium d crease the elevated temperature o dation resistance of titanium. A alloys of higher chromium conte oxidized at lower rates than titaniu in air but no alloy approached t performance of commercial austeni stainless steels.

Hot hardness values for the forge able alloys in the temperature rang 1200 to 1500 F were extremely low These alloys also showed relatively poor stress-rupture properties fro 1050 to 1250 F. These limitations along with those imposed by oxida tion, mean that forgeable titaniu chromium alloys cannot be recom mended for use as high-temperatur high-stress materials. However, the might be considered for temperatur below 1000 F and at stresses less th

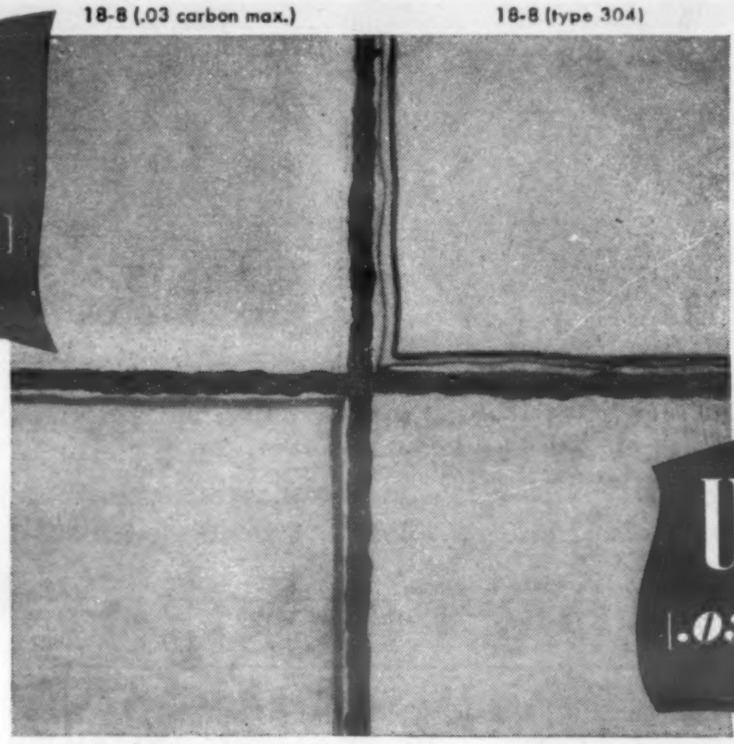
[T]wo new extra-low carbon

U·S·S Stainless Steels

[g]ive high corrosion resistance after welding

U·S·S 18-8
[.03 carbon max.]

18-8 (.03 carbon max.) 18-8 (type 304)



18-8Mo (type 316) 18-8Mo (.03 carbon max.)

U·S·S 18-8Mo
[.03 carbon max.]

[Th]is panel, composed of specimens [of] the four grades indicated, illus[trat]es dramatically how low car[bon] grades resist corrosion after [wel]ding. The panel was exposed [for] 6 hours to a 10% HNO_3, 3% [HF] solution at 80°C. Neither of [the] low carbon specimens shows [ev]idence of deterioration, while the [sta]ndard 18-8 (type 304) grade is [com]pletely severed at the critical [we]ld zone and the standard 18-8Mo [(ty]pe 316) specimen is severely at[tack]ed at this point.

[W]here to use these [lo]w-cost, low-carbon Stainless grades

- [W]elded tubing
- [S]moke stacks and duct[w]ork in chemical plants
- [D]rawn shapes for welded [a]ssemblies
- [H]oods and ducts in paper [a]nd textile plants
- [C]hemical extraction tanks
- [Su]lfite digesters
- [P]ickling tanks
- [C]hemical polishing tanks
- [B]ubble caps in distillation [u]nits

If you need a grade of Stainless Steel that must undergo exposure to exceptionally severe corrosive conditions after welding or hot forming, you'll find real savings in these two new grades of U·S·S Stainless Steel which contain a maximum of 0.03% carbon.

During exposure to sensitizing temperatures—800° to 1600°F.—some of the chromium in ordinary grades of Stainless combines with carbon to form chromium carbides, thus reducing corrosion resistance. Heretofore, fabricators have had to combat this by annealing the product or by the use of steel containing such stabilizing elements as columbium or titanium—both expensive operations.

Development of two new U·S·S Stainless Steels—U·S·S 18-8 [.03 carbon max.] and U·S·S 18-8 Mo [.03 carbon max.]—now makes the inconvenience of special treatment or the extra cost of stabilized grades in many applications unnecessary. In these new grades, the carbon content has been drastically reduced, practically eliminating the problem of carbide precipitation with resultant intergranular corrosion.

Corrosion tests of welded joints have indicated that these new grades give resistance to intergranular corrosion adjacent to welds equal to the more expensive stabilized grades and far in excess of ordinary grades.

By replacing stabilized grades with low carbon grades, you can realize savings in material costs up to 10%. In many cases, stress-relieving of welded vessels can be accomplished at substantially lower temperatures.

Get all the facts on these two new U·S·S Stainless Steels by writing for a copy of our booklet. Send your request to United States Steel Corporation Subsidiaries, 2207 Carnegie Building, Pittsburgh 30, Pa.

AMERICAN STEEL & WIRE COMPANY, CLEVELAND · CARNEGIE-ILLINOIS STEEL CORPORATION, PITTSBURGH
COLUMBIA STEEL COMPANY, SAN FRANCISCO · NATIONAL TUBE COMPANY, PITTSBURGH · TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM
UNITED STATES STEEL SUPPLY COMPANY, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST · UNITED STATES STEEL EXPORT COMPANY, NEW YORK

U·S·S STAINLESS STEEL

SHEETS · STRIP · PLATES · BARS · BILLETS · PIPE · TUBES · WIRE · SPECIAL SECTIONS

0-1845

UNITED STATES STEEL

News Digest

10,000 psi where low specific grav is a criterion.

Aluminum Coatings on Steel

The favorable corrosion resista of aluminum has resulted in the de velopment of many commercial pro esses for applying protective alu num coatings to ferrous materials. O these, the hot dipping process appe to hold an economic advantage. T paper "Effect of Bath Composition Aluminum Coatings on Steel" by D O. Gittings, D. H. Rowland and J. Mack, Carnegie-Illinois Steel Co covered the effects of various e ments on microstructure and be performance of hot-dipped coatin

Antimony, beryllium, bismuth, ca mium, calcium, chromium, cob copper, germanium, lead, magnesiu manganese, nickel, silicon, silver, t titanium, vanadium and zinc we added individually to the test bat

Of these elements, only silic copper and beryllium decreased th thickness of the alloy layer more th 50%. Only silicon and beryllium de creased the average microhardness the alloy layer. Silicon and berylli additions improved the flat-bend-t performance of the aluminum co ing but, in the concentration rang studied, beryllium was more effecti than silicon. Coatings containing bi muth, calcium, copper, germaniu magnesium, nickel, silicon, tin or zi did not have the attractive as-dippe surface appearance characteristic commercially pure aluminum coa ings.

Molybdenum Vapor Deposition

Molybdenum has a number of use ful physical and chemical properti including high melting point, hi temperature strength and resistanc to corrosion. Consequently there a many advantages that might be re ized by coating other metals with a adherent nonporous layer of moly denum of adequate thickness. A method of providing such a coatin was the subject of a paper title "Molybdenum Plating by Reductio of the Pentachloride Vapor" given b W. J. Childs, Lafayette College, an J. E. Kline, W. M. Kisner and Joh Wulff, Mass. Institute of Technolog

These investigators obtained mo lybdenum coatings by hydrogen re duction of molybdenum pentachlo ride vapor. It was found advisable keep total pressure at or below 2 mm mercury and temperature in th

range 1470 to 2010 F for maximum plating rate and optimum structure of the plate. Of the three distinct types of plate structure—fine grained, coarse-grained and laminated — the coarse-grained structure had the best physical properties.

Adhesion of the molybdenum coating to nickel or to a copper-nickel alloy containing at least 5% nickel was much better than to steel or pure copper. Thus, an intermediate electroplated layer of nickel improved the adhesion of molybdenum on steel. Optimum adhesion required the proper amount of interdiffusion; in the case of molybdenum on nickel, a plating temperature of 1740 F was recommended.

Powdered Beryllium

In the belief that pure beryllium may be inherently more ductile than data on currently available metal indicate, H. H. Hausner and N. P. Pinto, Sylvania Electric Products, Inc., have investigated "The Powder Metallurgy of Beryllium." Beryllium is of considerable commercial importance because of its good corrosion resistance, high strength-weight ratio and favorable nuclear properties.

The authors found that beryllium powder can be compacted at room temperature without difficulties and no binder is necessary to form the compacts. Sintering in a high vacuum or in a protective atmosphere such as argon below the melting point of beryllium produces a material of fairly high density. Beryllium sintered in a vacuum reveals measurable ductility, whereas argon-sintered beryllium compacts are brittle. Vacuum-sintered beryllium can be reduced 9% in thickness by cold rolling, and annealing permits further deformation.

Although these tests were made with an impure material, it is expected that the above conclusions will be helpful not only for further development of the powder metallurgy of beryllium but also for the development of the metallurgy of beryllium in general.

Hot Forming Light Metals

Economies resulting from "Hot Forming of Aluminum and Magnesium Alloys" were described by T. E. Piper, Northrop Aircraft, Inc.

Previously, when parts were formed

stainless is no pipe dream

There's no reason to blow smoke rings of fantasy about stainless steels. Since stainless steel is a versatile *family* of steels, the right analysis must be used or stainless will not perform its "miracles" in your application. Crucible, pioneer in the development of these specialty steels, makes freely available to you an alert staff of metallurgists — experts in the application of stainless. Crucible's engineers and metallurgists can show you the right grade and finish you need . . . and how Crucible Stainless offers you maximum satisfaction.

Whatever your application may be, Crucible is prepared to help you. Crucible's half century of specialty steel leadership is based on finding the best way to solve Industry-posed problems. Whether the order is in tons or pounds . . . your application will receive this same careful attention. When you think of stainless . . . call Crucible. CRUCIBLE STEEL COMPANY OF AMERICA, Chrysler Building, New York 17, New York.

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before heat treating, relief of induced stresses during heat treating, as well as non-uniform cooling afterward, resulted in serious warpage and dimensional changes. To correct the distorted shapes, mechanical straightening and makeshift shop practices were used. These in turn caused indeterminate prestressing, reduced mechanical properties and over-burdening of production facilities to an extent that output was retarded.

Now it has been found that forming at elevated temperatures is suitable for production fabrication of high-strength aluminum (75S) and magnesium alloys with substantial savings in time and man-hours. Hot forming reduces fabrication to a single operation and eliminates all check and straightening caused by heat treat warpage. By using temperatures on the order of 300 F and controlling time, mechanical property losses can be held to a negligible amount.

Both electrical resistance and hot oil bath heating methods have proved successful for elevated temperatures forming applications. In some cases where large parts are involved electrical air circulating furnaces are required.

Grindability

In "Grindability of Tool Steels," L. P. Tarasov, Norton Co., reported on a study of the relative ease of grinding for a large number of tool and die steels. He found that grindability could be expressed conveniently as a dimensionless index equal to the volume ratio of material removed in grinding to wheel wear. The higher this index, the easier the steel is to grind.

The grindability index for tool steels heat treated to ordinary commercial requirements is about 200 times greater for the easiest steel to grind than for the most difficult one. For steels in the same hardness range, the hardness of the carbide particles is the most important factor in determining the grindability. The higher the chromium content of nondeforming steels or the higher the vanadium content of high speed steels, the lower is the grindability index. Grindability of a tool steel improves as its Rockwell hardness is

(Continued on page 118)

News Digest

decreased, the percentage improvement being far greater for low- than for high-grindability steels.

Neither the surface finish obtained nor the susceptibility of the steel to surface cracking during or after grinding can be related in general to ease of removing stock. In addition, there does not seem to be any relationship between the grindability of the steel and the extent to which it is burned under severe grinding conditions, nor between grindability and grinding sensitivity.

News of Engineers

Lyman H. Allen, Jr. has been appointed chief engineer of Foster D. Snell, Inc. Mr. Allen formerly was assistant chief design engineer in charge of Chemical Process Design with the American Viscose Corp.

Ryan Aeronautical Co. has announced the promotion of ***Bruce Smith,*** chief engineer of Ryan's Airplane Div., to the position of director of engineering. Concurrently, W. T. Immerschuh was named executive engineer and principal aid to Mr. Smith.

R. H. Weigel has joined The National Radiator Co. as a senior research engineer. Mr. Weigel was formerly a special research assistant at the University of Illinois.

The appointment of *R. A. Hoffman* as director of research for Allied Research Products, Inc. has been announced. Mr. Hoffman joined Allied Research Feb. 1, 1950, having previously been associated with E. I. du Pont de Nemours & Co., Inc. as a research chemist and president of The R. A. Hoffman Chemical Co.

Dr. *Arthur E. Focke* has been named head of the Chemistry and Metallurgy Dept. of Fairchild Engine & Airplane Corp.'s NEPA Div. Dr. Focke had served as chief metallurgist of the Diamond Chain Co. since 1946, and will continue to be associated with the Company in an advisory capacity.

General Electric Co. has announced a number of appointments in its various divisions. Dr. *Alphonse Pechukas* has joined GE's Chemical Dept. as engineering manager for the Chemicals Div. He previously held the position of director of research for the Columbia Chemical Div.

News Digest

of Pittsburgh Plate Glass Co. The Chemical Dept. also promoted *John T. Castles* from manufacturing engineer to the position of manager of GE's silicone plant at Waterford, N. Y. In the Apparatus Dept., *Allan L. Davis* was named manager of service of the Transportation Divs., a newly-created position of evaluating and analyzing service requirements for the transportation industry. Mr. Davis formerly was manager of GE's ALCO-GE Service Engineering Div. Also from the Apparatus Dept. was announced the retirement of *J. Edmund Savage* from the Advertising and Sales Promotion Divs. after almost 44 years' service with GE. *Warren D. O'Neal* succeeds Mr. Savage as manager of the Production Div. and *C. Kenneth Emery* replaces Mr. O'Neal as manager of the Technical Publications Div. of the Advertising and Sales Promotion Divs. At the same time the Apparatus Dept. announced the promotion of *A. V. Feigenbaum* to the staff of manager of GE's Aircraft Gas Turbine Divs. Mr. Feigenbaum, who is succeeded by *B. R. Zimber* as supervisor of training for the Apparatus Dept., will also be connected with quality control activities for the company as a whole. Another announcement is that of the retirement of *R. D. Van Norstrand* as designing engineer in the Schenectady Industrial Heating Engineering Div. after 37 years of service with GE. And finally, Dr. *Irving Langmuir*, recently retired associate director of GE's Research Laboratory, was presented with the John J. Carty Gold Medal of the National Academy of Sciences. The Award is given once every two years in recognition of noteworthy contributions to the advancement of fundamental or applied science in any field.

Richard H. De Mott, vice president in charge of sales, is the new president of SKF Industries, Inc. He succeeds *William L. Batt*, who formally resigned to re-enter government service as chief of the ECA mission to the United Kingdom.

Ford Motor Co. has appointed *William F. Pioch* manager of manufacturing engineering of its newly-formed Aircraft Engine Div. Mr. Pioch, an employee of Ford for 38 years, was previously staff consultant to the department of manufacturing engineering.

Dr. *Franklin Strain* has assumed the position of acting director of research in charge of the Columbia Chemical Div. Laboratories of the Pittsburgh Plate Glass Co.

Westinghouse Electric Corp. has announced several appointments within the organization. *William C. Lilliendahl* was named research advisory engineer for the Westinghouse Lamp Div. and will direct the metals section of the research department. *L. R. Ludwig*, formerly manager of Westinghouse's Motor & Control Div.,

News Digest

is now assistant to the vice president. *Carl F. Herbold* was promoted to the position of director of manufacturing planning. And *K. H. Smith* succeeds Mr. Herbold as manager of Industrial Relations at the Westinghouse Small Motor Div.

Osborne Bezanson, vice president and member of the Executive Committee of Monsanto Chemical Co., has become president and a member of the board of directors of the Chemstrand Corp. He resigned from Monsanto to accept the new position with Chemstrand, a corporation jointly owned by American Viscose Corp. and Monsanto. Dr. *Carroll A. Hochwalt,* vice president of Monsanto and temporary president of Chemstrand, will continue as a member of the Chemstrand board of directors. It was also announced that *Harry L. Dalton,* vice president of American Viscose Corp., was named to the board of Chemstrand.

Carboloy Co., Inc. has made the following administrative appointments: *I. L. Wallace,* superintendent of the Carbide Metal Div., was named manager of engineering on both carbide and other special metals. *J. A. Muldoon,* superintendent of the Carbide Fabricating Div., was promoted to manager of manufacturing for carbides and other special metals. *R. L. Brownlee,* production manager on carbides, will also act in the same capacity for other special metals. *F. C. Ritner,* in addition to his responsibilities as vice president in charge of research, will also assist E. F. Wambold, executive vice president, in a general administrative capacity.

Albert H. Clem has been appointed to the newly-created position of assistant to the vice president in charge of sales of the Pennsylvania Salt Manufacturing Co. Mr. Clem was formerly assistant manager of sales in Pennsalt's Special Chemical Dept.

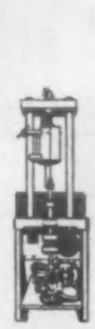
Koppers Co., Inc. has announced the retirement of *J. N. Forker* as vice president and general manager of its Tar Products Div. *Fred C. Foy,* formerly manager of the Sales Dept., succeeds Mr. Forker, and was elected a vice president of Koppers. It was also announced that *A. H. Engstrom* was named acting engineering manager of the Metal Products Div. of Koppers. He replaced Dr. *Tracy Jarrett,* who resigned.

John F. Byrne has joined Motorola as associate director of research in its Div. of Communications & Electronics. Since 1945 Mr. Byrne served as vice president and chief engineer of Airborne Instruments Laboratory, Inc.

Continental Can Co., Inc. has promoted *J. S. Snelham,* vice president and comptroller, to the newly-created position of vice president in charge of finance.

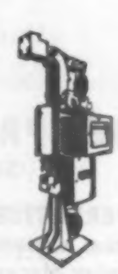
Harold L. Miner, nationally known in

These Baldwin testing machines have opened the door to many important new developments, by providing the designer with accurate knowledge of the properties of stressed materials under elevated temperatures. You'll find them invaluable aids in your investigations in this exciting new field.



BALDWIN CONSTANT STRAIN RATE CREEP TESTING MACHINE. Determines the effect of various strain rates on the breaking points of metals, at controlled high temperatures. Head velocity can be varied from 0.5″ to .000001″ per second. Ask for detailed information.

BALDWIN LEVER TYPE CREEP MACHINE. An extremely popular type; almost 200 are now serving in dozens of laboratories throughout the country. Maximum capacity 12,000 lb. Loading accuracy is within 1% of load, and accuracy of strain measurement is within 0.00005″. Ask for Bulletin 272.



BALDWIN RELAXATION TESTING MACHINE. Automatically carries out relaxation tests, providing a record of decline of load, in strain increments of only 0.000002″ per in. Produces a curve of stress vs. time on a flat chart. Capacity, 4000 lb. Accuracy is approximately 1% of load or .25% of capacity. Details on request.

BALDWIN SCREW TYPE CREEP RUPTURE MACHINE. Automatically maintains loads while temperature is held constant. Motor driven, capacity 20,000 lb. Flat recorder chart plots elongation vs. time. Information will be furnished on request.

Standard furnaces furnished with above equipment give temperatures up to 1800°F. Special furnaces available to provide temperatures up to 2200°F. Control limits are ±5°, or ± 2°, depending on controller used.

The Baldwin Locomotive Works, Philadelphia 42, Pa., U. S. A. Offices: Chicago, Cleveland, Houston, New York, Philadelphia, Pittsburgh, San Francisco, St. Louis, Washington. In Canada: Peacock Bros., Ltd., Montreal, Quebec.

BALDWIN

TESTING HEADQUARTERS

News Digest

the field of industrial safety and fire protection, has retired after serving 35 years with E. I. du Pont de Nemours & Co., Inc.

Hevi Duty Electric Co. has elected *Elton E. Staples* a vice president of the company. Mr. Staples will continue to manage the Cleveland office of Hevi Duty.

Dr. *R. H. Lueck* has been named general manager of research for the American Can Co. He will transfer his headquarters from the Hawaiian Islands, where he was manager of sales for the Company's Pacific Div., to the general offices in New York City.

The election of *James T. Chatterton* as vice president of Mackay Radio & Telegraph Co. has been announced. He will be in charge of the Company's activities on the West Coast, with headquarters in San Francisco.

Rem-Cru Titanium, Inc. has announced the following appointments: *C. I. Bradford,* formerly manager of the development division of Remington Arms Co., Inc., is now director of operations for Rem-Cru. *Edward L. Wemple* and Dr. *Walter L. Finlay,* both associated with Mr. Bradford at Remington, were named production manager and research manager, respectively.

George L. Fenn, secretary and assistant treasurer of Adamson-United Co., was recently elected to the Company's board of directors.

The promotion of *John A. Maxwell, Jr.,* formerly administrative assistant to the president, to the position of works manager has been announced by Texas Engineering & Manufacturing Co., Inc.

William Naden, director and general manager of manufacturing for Esso Standard Oil Co., was elected a vice president of the Company, and *Herbert P. Schoeck,* treasurer, was made a director. These appointments followed the resignation of *Marion W. Boyer,* a vice president and director, who accepted the post of general manager with the Atomic Energy Commission.

W. B. Horton, welding engineer for The Lincoln Electric Co., died recently at the age of 53.

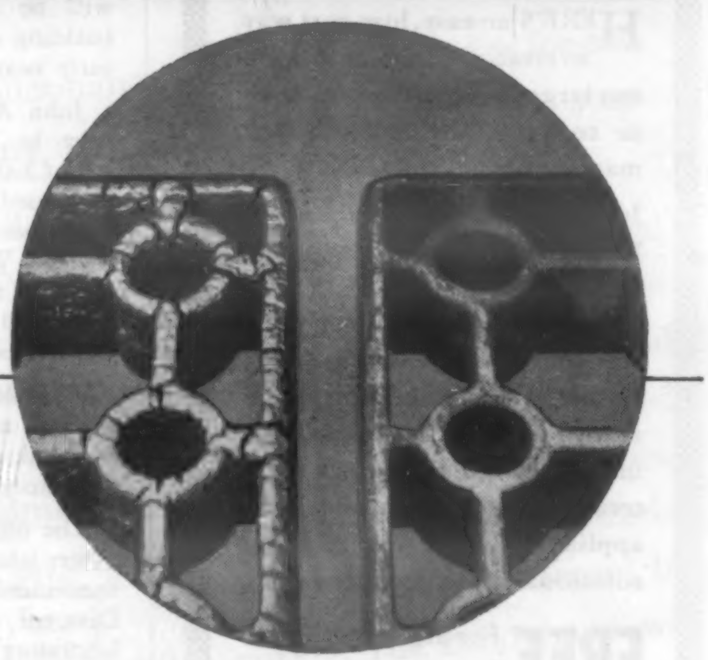
Carnegie Institute of Technology has announced the death of Dr. *Robert Ernest Doherty,* who recently retired from the Institute after a 14-year tenure.

Elmer Clark, executive and member of the engineering staff of Goodyear Tire & Rubber Co. for the past 39 years, died suddenly at the age of 68.

The International Nickel Co. of Canada, Ltd., has announced the death of *William F. Munday* after a brief illness. Mr. Munday had served as deputy comp-

ONCE THEY WERE TWINS

. . . but see the difference after 10 months' service!



THIS CLOSE-UP shows cracked condition of standard 35% Ni.—15% Cr. analysis tray on left . . . compared to THERMALLOY* "58B" tray on right. Both were in identical service for a 10-month period. THERMALLOY "58B" was recommended by Electro-Alloys engineers to improve service life for this application.

The heat treat trays shown above were part of an order supplied to a large automotive manufacturer by Electro-Alloys. *On the left* is a tray of standard analysis (35% Ni.—15% Cr.) which had been specified and used by the customer for some time. *On the right* is a tray of special analysis—THERMALLOY "58B"—recommended by our metallurgists after a careful study of the job requirements.

At our suggestion, a split order was placed on a trial basis. The pictures, taken after 10 months in carburizing service followed by an oil quench, tell their own story. Standard trays (left) had failed completely. They were badly checked and showed "growth" of as much as ⅜ of an inch on one dimension. Trays of THERMALLOY "58B" (right)—with exactly the same amount and kind of service—barely showed signs of use. There was no checking or cracking and "growth" was scarcely measurable.

Here's proof that expert metallurgical knowledge *can* make a substantial difference in the life of heat treat parts. To put such knowledge to work for you, just phone your nearest Electro-Alloys office, or write Electro-Alloys Division, 1990 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN **Brake Shoe** COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

News Digest

troller for both the Canadian concern and its U. S. subsidiary, The International Nickel Co., Inc.

News of Companies

The Dow Chemical Co., Midland, Mich., has begun construction of two new plants. The one near New London, Conn., is being built for the manufacture of Styron, a Dow plastic, and is expected to be completed within a year. The other plant will be an addition to Dow's plastics building at Midland, and should be ready early next fall.

John A. Evans, formerly project engineer in the electronics section of the Allis-Chalmers Manufacturing Co., has purchased the business and equipment of the *Kenworth Metal Stamping Co.*, Milwaukee, Wis. Mr. Evans is the new president and treasurer of the organization, but there will be no other change in the production personnel.

The Milwaukee Die Casting Co. is erecting a new plant on N. Holton St. in Milwaukee, Wis., which will be ready for occupancy by February or March 1951.

The official opening of a new measurements laboratory in Lynn, Mass., has been announced by the Meter & Instrument Divs. of *General Electric Co.* The new laboratory contains complete facilities for applied research product development and design in the field of measurements.

The F. J. Stokes Co., Philadelphia, has launched a $700,000 expansion program, adding one-third in space to the present plant. Completion is scheduled for early 1951.

The manufacture of monoethanolamine, diethanolamine and triethanolamine by the *Jefferson Chemical Co., Inc.*, New York 22, will begin as soon as construction of a new plant in Port Neches, Tex. has been completed, sometime during the latter half of 1951.

Lenkurt Electric Co., San Carlos, Calif., and Vancouver, Canada, has begun the building of an addition to its San Carlos plant.

Beryllium copper springs and stampings are now being produced by *Lee Mechanical Laboratories*, a division of *Lee Spring Co., Inc.*, Brooklyn 1, N. Y.

National Lead Co. has begun construction of two new sulfuric acid plants, one to be located in St. Louis, the other in Sayreville, N. J. Output of the new plants will be used to expand National Lead's titanium pigment facilities.

News Digest

Operations are scheduled to begin about Jan. 1, 1951 in a new plant being erected by *The Barry Corp.*, Cambridge, Mass., in Watertown, Mass. The expanded facilities will more than double the present floor space devoted to the production of shock mountings and vibration isolators.

The Research Corp., Brooklyn, N. Y., has awarded a $2500 fellowship to Roscoe Guernsey, Jr., assistant professor of mechanics at the University of Texas. The fellowship is established at the Illinois Institute of Technology, and provides for the study of photoelastic stress analysis.

News of Societies

The *American Welding Society* has elected Harry W. Pierce as its president for the coming year. Mr. Pierce is assistant to the president of the New York Shipbuilding Corp. First vice president is Charles H. Jennings, engineering manager of the Welding Dept., Westinghouse Electric Corp. Mr. Jennings was also selected as the 1950 Adams Lecturer, an honor awarded annually to an outstanding welding scientist or engineer. Second vice-president named for 1950-1951 was Fred L. Plummer, director of engineering, Hammond Iron Works. It was also announced that Dr. Wendel F. Hess, head of the Dept. of Metallurgical Engineering at the Rensselaer Polytechnic Institute, was the recipient of the Samuel Wylie Miller Memorial Award, presented by the Society for conspicuous contributions to the advancement of welding and cutting of metals. During the annual meeting in October, the Society also presented $2,000 in prizes to the winners of the 1950 Resistance Welder Manufacturers Assn. contest. They included J. W. Kehoe, Westinghouse Electric Corp., first prize; A. O. Bergholm, P. W. Swartz and G. S. Hoell, engineers at The Franklin Institute, second prize; and I. S. Goodman, Westinghouse, third prize. For the best paper from a University source, Dr. Georges Welter, University of Montreal, won first prize; and Dr. W. B. Kouwenhoven, Johns Hopkins Institute, and Dr. W. T. Sackett, Jr., Battelle Memorial Institute, were second prize winners.

Sidney J. Williams, assistant to the president of the National Safety Council, has been chosen by the *Society of Automotive Engineers* as the fourth David

News Digest

Beecroft Memorial Lecturer for his "substantial contributions to the safety of traffic involving motor vehicles". It was also announced that Dr. Daniel P. Barnard, IV, research coordinator for Standard Oil Co. (Indiana), will receive the 1949 Horning Memorial Award at the 1951 annual meeting of the Society. The Award is presented "in recognition of distinguished active service in the field of mutual adaptation of fuels and engines".

Dr. Leonard Greenstone, formerly assistant professor at the University of California, has joined the Dept. of Applied Physics at *Stanford Research Institute.*

The Conveyor Equipment Manufacturers Assn. elected the following officers during its annual meeting: president—L. B. McKnight, vice president, Chain Belt Co.; vice president—G. W. Ostrand, general manager of the Caldwell Plant, Link Belt Co.; treasurer—Earl D. Stearns, general manager, Conveyor Div., Barber-Greene Co.; and secretary—Lee Sekulski, sales manager, Mathews Conveyor Co. R. C. Sollenberger was re-elected executive vice president.

The Armour Research Institute of the *Illinois Institute of Technology* has announced the following appointments: Dr. Christopher E. Barthel, Jr. has been named assistant director in charge of personnel. Dr. E. H. Schulz succeeds Dr. Barthel as acting chairman of the physics dept. at the Foundation. Dr. John T. Rettaliata, dean of engineering, was named vice president for academic affairs and continues as dean. Raymond J. Spaeth, executive secretary and treasurer, becomes vice president for business affairs and continues as treasurer. Dr. Haldon A. Leedy, director of the Foundation, was made vice president of the Foundation, and continues as director. And finally, Walter C. Troy was promoted to the position of assistant chairman of the Metals Research Dept. of the Foundation.

Robert H. Seavy has been appointed assistant director of the Graduate School and the Industries Training School of *Stevens Institute of Technology,* with the title of assistant professor.

T. B. Jefferson, editor of *The Welding Engineer* and *The Welding Encyclopedia,* has been named to the advisory committee of the Welding Institute at the *Milwaukee School of Engineering.*

Walter C. Teagle, former president and chairman of Standard Oil Co. (New Jersey), has been designated as the 1950 recipient of the *American Petroleum Institute's* Gold Medal for Distinguished Achievement. The Medal is awarded to prominent Americans who have made outstanding contributions to public welfare through the petroleum industry.

Meetings and Expositions

INSTITUTE OF THE AERONAUTICAL SCIENCES, Wright Brothers Lecture. Washington, D. C. December 16, 1950.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, annual meeting. Cleveland. December 26-31, 1950.

SOCIETY OF AUTOMOTIVE ENGINEERS, annual meeting. Detroit. January 8-12, 1951.

PLANT MAINTENANCE SHOW AND CONFERENCE. Cleveland. January 15-18, 1951.

SOCIETY OF PLASTICS ENGINEERS, INC., national conference. New York, N. Y. January 18-20, 1951.

MALLEABLE FOUNDERS' SOCIETY, semi-annual meeting. Cleveland. January 19, 1951.

AMERICAN SOCIETY OF HEATING & VENTILATING ENGINEERS, annual meeting. Philadelphia. January 22-26, 1951.

INSTITUTE OF THE AERONAUTICAL SCIENCES, annual meeting. New York, N. Y. January 29-February 1, 1951.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, annual meeting. St. Louis. February 18-22, 1951.

PITTSBURGH CONFERENCE ON ANALYTICAL CHEMISTRY & APPLIED SPECTROSCOPY. Pittsburgh, Pa. February 28-March 2, 1951.

AMERICAN SOCIETY FOR TESTING MATERIALS, spring meeting and committee week. Cincinnati. March 5-9, 1951.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS, annual conference and exhibition. New York. March 13-16, 1951.

AMERICAN SOCIETY OF TOOL ENGINEERS, annual meeting. New York. March 15-17, 1951.

WESTERN METAL CONGRESS AND EXPOSITION. Oakland, Calif. March 19-23, 1951.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, Open Hearth and Blast Furnace, Coke Oven and Raw Materials conference, Iron and Steel Div. Cleveland. April 2-4, 1951.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, spring meeting. Atlanta, Ga. April 2-5, 1951.

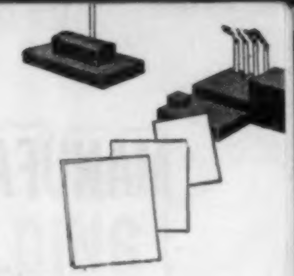
ELECTROCHEMICAL SOCIETY, spring meeting. Washington, D. C. April 8-11, 1951.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Process Industries conference. Baltimore, Md. April 17-19, 1951.

AMERICAN CERAMIC SOCIETY, annual meeting. Chicago. April 22-26, 1951.

AMERICAN FOUNDRYMEN'S SOCIETY, annual convention. Buffalo, N. Y. April 23-26, 1951.

MATERIALS HANDLING EXPOSITION. Chicago, Ill. April 30-May 4, 1951.



MANUFACTURERS' LITERATURE

Materials

Irons • Steels

Steel Selection. Climax Molybdenum Co., 72 pp. Information to help steel users choose proper steels and treatments to meet their design requirements. (1)

Steel Sheets and Wire. Continental Steel Corp., 20 pp, ill. Specifications and description of wide range of steel sheets and wire. Includes handy tabular aids to specification. (2)

Stainless Steel. Crucible Steel Co. of America, 31 pp, ill. Shows, through applications in textile industry, savings available to users of stainless steel. (3)

Low Alloy Steel. Inland Steel Co. Data on easy-to-fabricate Hi-Steel, strong, abrasion and corrosion resistant structural steel with high fatigue strength. (4)

Machinable Steel. Jones & Laughlin Steel Corp. Properties and grades of J & L "E" Steel, said to have high machinability, give better finishes, and extend tool life. (5)

Steel Bars. La Salle Steel Co. Describes Stressproof cold-finished, carbon steel bars said to combine high strength, machinability, wearability and minimum warpage. (6)

Clad Steels. Lukens Steel Co., 2 pp, ill, No. 540. Describes economies available through use of chromium- and nickel-clad steels. (7)

Screw Steel. Joseph T. Ryerson & Son, Inc., 2 pp. Describes Ledloy, claimed to machine 30 to 50% faster than the fastest cutting screw steel previously available. (8)

Low Alloy and Stainless Steel. Sharon Steel Corp., 4 pp, ill, No. Ia/26. Details of company's stainless, high-tensile, low alloy steels, Cor-Ten and N-A-X. (9)

Nonferrous Metals

Bronze Casting Alloys. American Manganese Bronze Co., 4704 Rhawn St., Philadelphia 36, Pa., 46 pp. Compositions, characteristics and applications of bronze casting alloys. Request directly from American Manganese.

Machining Aluminum Bronze. Ampco Metal, Inc., 12 pp, ill, No. 66a. Detailed instructions for machining and finishing Ampco Metal Grades. (10)

Rhodium. Sigmund Cohn Mfg. Co., 4 pp. Properties of rhodium and its value in electroplating due to its color, hardness and high corrosion resistance. (11)

Corrosion Resistant Alloys. The Cooper Alloy Foundry Co., 4 pp. Indicates resistance of corrosion resistant alloys against approximately 400 corrosive chemicals. (12)

Spring Alloy. Elgin National Watch Co., Industrial Products Div., 2 pp. Composition and properties of Elgiloy, cobalt-chromium-base spring alloy. (13)

Aluminum Alloy. Frontier Bronze Corp. Data on Frontier 40-E aluminum alloy combining high strength, good shock and corrosion resistance, and machinability. (14)

Aluminum. Reynolds Metal Co., Louisville 1, Ky., 96 pp, ill, No. RMC-12. Detailed description of aluminum production. Available direct from Reynolds.

Nonmetallic Materials • Parts

Molded Soft Rubber. Acushnet Process Co., 32 pp, ill, No. 50. Describes facilities for making wide range of precision molded soft rubber parts to order. (15)

Porcelain Insulators. The Akron Porcelain Co., 6 pp, ill. Shows numerous insulating parts of various porcelains and briefly describes engineering properties of porcelain. (16)

Felts. American Felt Co. Technical standards for felt materials adopted by automotive and many other industries. Includes sample felts. (17)

Hard Rubber. American Hard Rubber Co., 60 pp. Manual gives detailed selection data on hard rubber and plastics materials. (18)

To obtain literature appearing on these pages, please refer to easy-to-use reply card on page 137

Rubber Parts. Automotive Rubber Co., Inc. Series of bulletins show use of rubber for insulation or corrosion prevention in industrial equipment. (19)

Plastics. Bakelite Div., 24 pp, ill, No. G-8. Properties, descriptions and numerous applications of various Bakelite and Vinylite plastics. (20)

Porcelain Products. The Colonial Insulator Co., 12 pp, ill. Shows wide range of custom made porcelain products including insulators, forms for dipped rubber goods, and kitchen appliances. (21)

High Strength Plastics. Continental-Diamond Fibre Co., No. GF-50. Properties, descriptions and applications of five high strength plastics. (22)

Plywood. Douglas Fir Plywood Assn., 32 pp, ill. Series of articles shows how to use plywood effectively in fixtures, displays, posters and signs. (23)

Plastics. Durez Plastics & Chemicals, Inc. *Durez Plastics News* gives monthly information on company's plastics and developments. (24)

Cellulose Ester Materials. Eastman Kodak Co., Cellulose Products Sales Div., 8 pp, ill, No. H-1-10. Data and specifications for Kodapak Sheet, thermoplastic cellulose ester with good electrical qualities. (25)

Flexible Tubing. Flexible Tubing Corp., 8 pp, ill, No. 5-4. Applications and performance data on Spiratube, flexible tubing for ventilation and materials conveying. (26)

Plastics. General Electric Co., Plastics Div., 16 pp, ill, No. 16/13. Characteristics, uses and properties of this company's various molded and laminated plastics. (27)

Plastic-Faced Plywood. Georgia-Pacific Plywood & Lumber Co., 4 pp, ill. Applications, properties and description of GPX high grade exterior plywood coated with plastic. (28)

Rubber. B. F. Goodrich Chemical Co. Properties and applications of Hycar, high strength compression and heat resistant rubber suited to heavy duty service. (29)

Packing. Greene, Tweed & Co., 16 pp, ill, No. PC-101. Specifications, descriptions and applications of Palmetto packing, gaskets, asbestos rope and wick. (30)

MANUFACTURERS' LITERATURE

Thermoplastic Resin. Hercules Powder Co., Naval Stores Dept., 12 pp, No. 400-332 A. Detailed properties, applications and available forms of Vinsol resin. (31)

Apparatus Porcelain. Locke Inc., 12 pp, ill, No. 518. Discusses characteristics and limitations of ceramic processes as an aid to designing apparatus porcelain. (32)

Carbon Products. Morganite, Inc., 8 pp, ill, No. 1f. Specifications of various carbon bearings and bushings. Also properties of six series of Morganite carbon products. (33)

Plastics. Naugatuck Chemical Div., U. S. Rubber Co. Technical reports on this company's new developments in lamination curing, resin types, dyes and applications. (34)

Corrosion Resistant Materials. Nukem Products Corp., 36 pp, ill. This company's line of acid-proof brick, membranes, cements and structures, including tables of properties and specifications. (35)

Thermosetting Plastic. Plaskon Div., Libbey-Owens-Ford Glass Co., 2 pp, ill. Lists advantages and shows application of Plaskon alkyd plastic. (36)

Hose, Molded Parts. Resistoflex Corp., 4 pp, ill, No. 4g/3. Properties and uses of this company's resinous-lined, reinforced industrial hose and custom-molded parts. (37)

Cellular Rubber. Rubatex Div., Great American Industries, Inc., No. RBS-12-49. Describes Rubatex closed cell rubber for use as cushioning, gasketing and shock-absorbing. (38)

Ceramic Properties. D. M. Steward Mfg. Co., 4 pp, ill. Tables of properties of steatites, semi-steatites, cordierites, mullites, zircon porcelains and fired stones. (39)

Ceramic. Stupakoff Ceramic & Mfg. Co., 4 pp, No. 849. Properties of Stupalith, new ceramic said to be unsurpassed in thermal shock resistance. (40)

Inert Plastic. U. S. Gasket Co., Teflon Products Div. Catalog No. 300. Description and complete specifications of available stock of Teflon, chemically inert, electrically resistant plastic. (41)

Carbon Graphite. U. S. Graphite Co., 4 pp, ill. Describes Graphitar, carbon-graphite nonmetallic that is chemically resistant, self-lubricating, hard, light and won't warp. (42)

Polyvinyl Resins. U. S. Rubber Co., Naugatuck Chemical Div., 20 pp, ill. Discusses properties, ingredients and processing of Marvinol polyvinyl chloride resins. (43)

Metal Parts • Forms

Aluminum Die Castings. Aluminum Co. of America. Book contains detailed technical information for effective design of aluminum die castings. (44)

Aluminum Extrusions. Aluminum Co. of America. Design potentials of extrusion process and cost savings in fabrication and assembly of extrusions explained. (45)

Aluminum Parts. Aluminum Goods Mfg. Co., 56 pp, ill. Catalog covers extensive production facilities and technical services for producing wide range of parts. (46)

Pre-Finished Metals. American Nickeloid Co. Data on properties, tempers and finishes of pre-finished brass, zinc, aluminum, copper and steel based metals. (47)

Stainless Steel Parts. Amplex Mfg. Co., 1 p, ill. Describes bearings, finished machine parts and permanent filters made from Oilite stainless steel. (48)

Nonferrous Plaster Mold Castings. Atlantic Casting & Engineering Corp., No. 4. Describes production of copper-base and aluminum alloy "Atlanticastings". (49)

Aluminum Bronze Die Castings. Aurora Metal Co., 8 pp, ill. Description, advantages and sample products of firm's vacuum die casting process. Technical details of alloys used. (50)

Small Parts. The Bead Chain Mfg. Co. Data bulletin describes company's Multi-Swage Process for economical manufacture of small metal parts up to ¼-in. dia and 2-in. lengths. (51)

Steel Forms. Bethlehem Steel Co., 4 pp, ill, No. 1a/8. Advantages of company's cold-formed shapes, including Mayari R, low alloy, high strength steel, forgings and wires. (52)

Magnesium Parts. Brooks & Perkins, Inc., ill. Folder gives table of characteristics, design data and applications of magnesium products. (53)

Stainless Tubing. Carpenter Steel Co., Alloy Tube Div., 4 pp, ill. Physical properties, corrosion resistance and available sizes of this company's stainless tubing. (54)

Powdered Metal Parts. Chicago Metal Products Co., 4 pp, ill. Properties and advantages of Camet custom-molded powdered metal parts. Includes design types. (55)

Stampings. Detroit Stamping Co., 4 pp, ill. Shows wide variety of stamped parts demonstrating versatile stamping facilities for custom making parts. (56)

Magnesium Die Castings. Doehler-Jarvis Corp., 4 pp, ill. Physical properties, applications and advantages of Doler-Mag magnesium die castings. (57)

Magnesium Forms. Dow Chemical Co., Magnesium Div. Technical information on magnesium, its available forms and applications. (58)

Die Cast Parts. The Electric Auto-Lite Co., Die Casting Div., 16 pp, ill, No. G137. Describes facilities for economical manufacture of quality die castings. (59)

Steel Tubes. Globe Steel Tubes Co., 8 pp, ill, No. 1a/12. Specifications and tolerances of Gloweld-welded seamless tube and pipe of Globe-iron and steel. (60)

Self-Lubricating Bushings. Graphite Metallizing Corp., 8 pp, ill. Describes Graphalloy grades for bushings and electrical uses. Bearing design data included. (61)

Investment Castings. Gray-Syracuse, Inc., 4 pp, ill. Various parts of precision-cast brass, bronze, beryllium, copper and steel. (62)

Precision Castings. Haynes Stellite Div., Union Carbide and Carbon Corp., 20 pp. Describes applications and advantages of custom-made precision cast parts. (64)

Perforated Metal. Hendrick Mfg. Co., 4 pp, ill. Several applications and various examples of standard types of perforated sheet metals. (65)

Sleeve Bearing Design. Johnson Bronze Sleeve Bearing Headquarters. Series of data sheets with detailed design data for manufacturing good sleeve bearings. (66)

Aluminum Cable. Kaiser Aluminum & Chemical Corp. Properties of Kaiser Aluminum ACSR and All-Aluminum Cable. Tables of reel sizes given. (67)

Aluminum Extruded Shapes. Light Metals Corp., 6 pp, ill. Shows facilities for producing a variety of aluminum fabrications and extruded shapes to order. (68)

Gray Iron Castings. Meehanite Metal Corp., 8 pp, ill, No. 30. One of a series of bulletins describing current uses of Meehanite castings. (69)

Tungsten Carbide Rolls. Metal Carbides Corp., 16 pp, No. CR-50. Detailed description of tungsten carbide rolls for cold rolling mills, including properties and advantages. (70)

Powder Metal Parts. Metals Refining Co., Div. of the Glidden Co., 16 pp, ill. Describes fabrication of iron, copper and lead powder metal parts, and discusses limitations and advantages of powder metallurgy. (71)

Precision Castings. Microcast Div., Austenal Laboratories, Inc., 16 pp, ill. Advantages, design factors and wide applications of Microcast precision castings. (72)

Zinc Die Castings. The New Jersey Zinc Co., 8 pp, ill. *The Alloy Pot* gives monthly developments and applications of zinc die casting. (73)

Seamless Aircraft Tubing. Ohio Seamless Tube Co., 70 pp, No. A-2. Specifications, tolerances, physical properties and uses of steel seamless aircraft tubing. (74)

Powder Metal Parts. Powder Metal Products Inc., 4 pp, ill, No. 350-5. Shows numerous cost-saving applications of powder metallurgy in parts and bearings. (75)

Wire Cloth. Reynolds Wire Co., 8 pp, ill, No. 1a/30a. Available materials, styles and sizes of industrial wire cloth, furnished in ferrous and nonferrous materials. (76)

MANUFACTURERS' LITERATURE

sting Metal Parts. Magnaflux Corp., 8 pp, No. B-415-2. Describes magnetic parti- inspection of metal parts, and shows variety of industrial applications. (145)

ntainer Testing Machine. National Forge d Ordnance Co., Testing Machine Div., pp, ill, No. 491. Features of compression machine for studying container strength. (146)

ectronic Thickness Gage. Sperry Products, c., 4 pp, ill, No. 3700. Describes Reflecto- ge, thickness gage enabling thickness termination from one side only. (147)

inell Hardness Tester. Steel City Testing achines, Inc., 2 pp, ill, No. H 249. escription, specifications and operating in- ructions of hand operated Brinell hardness ster. (148)

astics Tests. U. S. Testing Co., Inc., 2 pp. ice list of physical, chemical, micro-bio- gical and permanence tests available for astics film, sheeting and coated fabrics. (149)

hermocouples. Wheelco Instruments Co., 8 pp, ill. Catalog gives specifications and scriptions of complete line of thermo- uples, control instruments and accessories. (150)

General

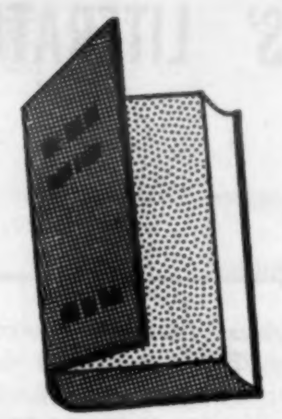
Hydraulic Tables. Baldwin Locomotive Works, 40 pp. Extensive tabular data on hydraulic equipment, particularly in load-producing applications to testing machines. (151)

Ultrasonic Equipment. The Brush Development Co., Hypersonic Div., 4 pp, ill, No. F-267. Uses and specifications of Hypersonic Equipment for ultrasonic energy applications such as emulsification, dispersion and degassing. (152)

Chain and Belt Conveyors. Michigan Steel Casting Co., 8 pp, ill, No. 1-B. Shows Misco rivetless chain conveyors and Woodman belt conveyors for high temperatures. (153)

Industrial Solvents. Solvents and Chemicals Group, folder. Describes services of this group as reliable producers of industrial solvents and chemicals. (154)

Turbo-Compressors. The Spencer Turbine Co., 12 pp, ill, No. 107 B. Description, characteristics and applications of multi-stage turbo compressors. Includes tables and charts. (155)



BOOK REVIEWS

Plastics and Resins

A Manual of Plastics and Resins in Encyclopedia Form. *By William Schack. Published by the Chemical Publishing Co., Inc., Brooklyn, N. Y., 1950. Cloth, 6¼ by 9¼ in., 547 pages. Price $10.00.*

This comprehensive but compact survey of the materials, processes, products and equipment of the plastics industry contains some 1500 different subjects arranged in alphabetical order for ready reference.

In addition to full-length articles on many subjects, the book includes hundreds of short articles on products and definitions of basic molding, fabricating and chemical terms. Ample cross-references have been provided to guide the reader to information which may appear under more than one heading.

In addition, the major fields of plastics applications, such as aircraft, automotive, electrical appliances, housewares, refrigerators, etc., are all discussed in detail. Each article gives not only the components for which plastics are used but also the specific plastic used for each and the properties which make it suitable for that purpose.

Metals at Low Temperatures

The Properties of Metallic Materials at Low Temperatures. *By P. Litherland Teed. Published by John Wiley & Sons, Inc., New York 16, N. Y., 1950. Cloth, 5¾ by 8¾ in., 222 pages. Price $3.50.*

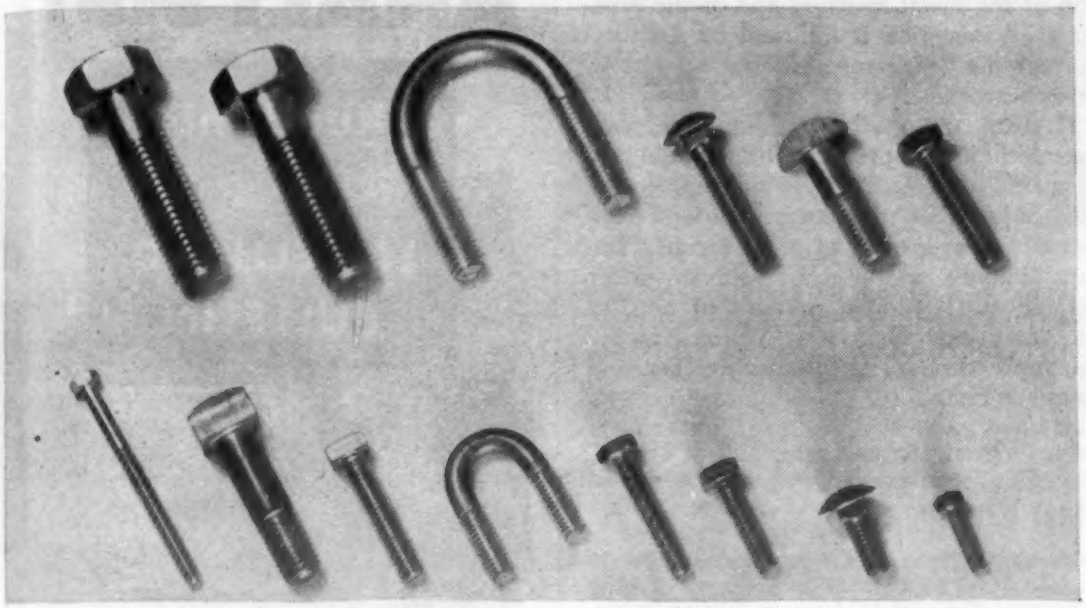
Increasing industrial applications for refrigeration and the advent of flying in the lower stratosphere have given impetus to the search for more information on the properties of metals at low temperatures. Despite great advances in experimental and theoretical physics, it is still impossible to predict what will happen to a metal at one temperature by using data collected at another temperature. Therefore, this book is in the form of a critical survey of a large number of experiments.

The book begins with a broad review of the subject in relation to fundamental physics. Seven chapters are devoted to consideration of some of the major mechanical properties at low temperatures of alloys

COPPER ALLOY BULLETIN

REPORTING NEWS AND TECHNICAL DEVELOPMENTS OF COPPER AND COPPER-BASE ALLOYS

Prepared Each Month by BRIDGEPORT BRASS COMPANY "Bridgeport" *Headquarters for BRASS, BRONZE and COPPER*



Various types of bolts with rolled threads using silicon bronzes. Courtesy—Russell, Burdsall & Ward Bolt and Nut Company, Portchester, N. Y.

Silicon Bronzes, Correct Tooling Insure Long Life for Bolts, Nuts

The desire of manufacturers to produce bolts and nuts capable of withstanding corrosion and its gradual weakening of parts has led to a widespread use of the silicon bronzes.

The ability of these bronzes to withstand season cracking and other forms of corrosion and their high tensile strengths make them excellent for all types of nuts and bolts, wire and cable connectors, pole line and marine hardware, water meter bolts and valve parts.

Tensile strengths up to 90,000 psi can be obtained in cold formed bolts with silicon bronze No. 609 (approx. 98% copper and 2% silicon).

Silicon Bronze Very Malleable

This bronze is very malleable even in a hard drawn condition, permitting good flow of metal in difficult cold forming applications.

Materials, machines and tools are important factors in cold heading. The choice of the header, in regard to size and number of strokes, depends on the amount or length of material needed to form the upset; the length of the shank under the head, the location of the upset portions on the product and the shape.

Temper Important

Care must be taken in selecting the temper for each cold forming job. If the head is large and thin, softer temper with its increased malleability is advised to prevent heavy tool wear. If the upset is not too severe, then harder temper can be used.

Since cold forming and rolled threading increases the hardness of silicon bronze, the amount of cold work for each job should also be analyzed and temper selected to give the desired tensile strength in the finished piece.

Choice of Header

An approximate formula for the selection of the proper type of header utilizing standard heading practices follows:

1-stroke ...... $L = 2D$
2-stroke ...... $L = 4D$
3-stroke ...... $L = 6D$

D = wire diameter
S = length of wire for shank
L = length of wire for head

Silicon bronzes can be upset to 20 diameters compared to the finished shank diameter by extruding and upsetting in each stage in multiple-station header.

Work in excess of 15 diameters in length of shank should be fabricated in an open die header which is built to open the dies to relieve the pressure on the knockout pins.

These pins are normally made from high carbon steel drill rod.

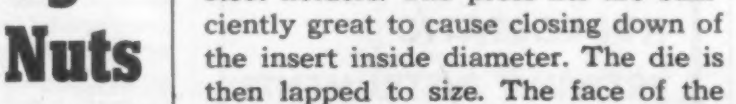
Steel Inserts Used

High chrome, high carbon steel inserts have been used successfully in round dies. These inserts are turned, hardened in a neutral atmosphere which will prevent decarburization or carburization, then pressed into soft steel holders. The press fits are sufficiently great to cause closing down of the insert inside diameter. The die is then lapped to size. The face of the bushing is held to exactly the same diameter as the head of the bolt. If a larger diameter is used, cracking and chipping of the hardened bushing is possible.

Flow of metal is dependent on the design of die and punch as well as the ductility of the alloy. Working backward from the finished part, definite flow characteristics of the metal can be studied and the coning punches designed to control the flow toward the finished item in two or three-stroke headers.

Laboratory Help Available

For information of the silicon bronzes and other cold heading alloys, Bridgeport's Laboratory is prepared to cooperate with fabricators of coldheaded parts. Write for Duronze manual.



Stages in production of silicon bronze nut in nut machine—four blows and pierce. Slug is at end. Courtesy—Russell, Burdsall & Ward Bolt and Nut Company, Portchester, N. Y.

Book Reviews

(continued)

of aluminum, iron, magnesium, copper, nickel, zinc, tin and lead. Ferritic and austenitic steels, because of their outstanding importance as engineering materials, are given three chapters. In each case a description of the metal structure and of the process of deformation is followed by a discussion of the effects of deformation and of heat treatment.

Physical and mechanical properties covered include: proportional limit; yield and ultimate strengths in tension, compression and shear; yield strength in bearing; elongation and reduction of area; notched impact strength and notch sensitivity under static loading; fatigue strength of notched and unnotched specimens; Young's modulus, shear modulus and bulk modulus; and Poisson's ratio.

Other New Books

Recommended Practices for Resistance Welding. *Prepared by the A.W.S. Resistance Welding Committee. Published by American Welding Society, New York 18, N. Y., 1950. Paper, 6¼ by 9 in., 60 pages. Price $1.00.* This new, revised and enlarged edition represents a modification and expansion of the Standard originally issued in tentative form in 1946 by the American Welding Society. It is an excellent guide for setting up welding schedules to be followed in any particular fabrication, modified according to the specific fabricating conditions and production requirements involved.

Proceedings of the Sixth Annual Meeting of the Metal Powder Association. *Published by the Metal Powder Assn., New York 17, N. Y., 1950. Paper, 6 by 9 in., 92 pages. Price $2.50.* All the formal papers offered at the sixth annual meeting of the Metal Powder Assn., held in Detroit Apr. 25-26, 1950, with discussions, and the transcript of an interesting informal session on powder metallurgy.

Machinery's Handbook. 14th Edition. *By Erik Oberg & F. D. Jones. Published by the Industrial Press, New York 13, N. Y., 1949. Cloth, 5 by 7¼ in., 1911 pages. Price $7.00.* A comprehensive reference book on machine design and shop practice for the mechanical engineer, draftsman, toolmaker and machinist.

Welding Patent Classification in the A. F. Davis Welding Library. *By Robert S. Green. Published by College of Engineering, Ohio State University, Columbus 10, Ohio, 1950. Paper, 6 by 9 in., 74 pages. Price 75c.* Engineering Experiment Station Bulletin No. 140 gives an outline of the Patent Classification Index of the A. F. Davis Welding Library, and explains in detail the operation and use of the system.

Industrial Instrumentation. *By Donald P. Eckman. Published by John Wiley & Sons, Inc., New York 16, N. Y., 1950. Cloth, 5¾ by 8½ in., 396 pages. Price $5.00.* An introduction to the science of measurement that completely covers the instrument field, including mechanical, chemical and electrical applications.

Pocket Encyclopedia of Atomic Energy. *By Frank Gaynor. Published by the Philosophical Library, New York 16, N. Y., 1950. Cloth, 5¾ by 8¾ in., 204 pages. Price $7.50.* A comprehensive collection of brief explanations and definitions of concepts and terms in the field of nuclear physics and atomic energy.

Report on the Strength of Wrought Steels at Elevated Temperatures. *By R. F. Miller & J. J. Heger. Published by the American Society for Testing Materials, Philadelphia 3, Pa., 1950. Paper, 8½ by 11 in., 109 pages. Price $3.00.* Complete information and data on the chemical and physical properties of wrought steels at elevated temperatures, issued under the auspices of the A.S.T.M.-A.S.M.E. Joint Committee on Effect of Temperature on the Properties of Metals.

Bond Testing of Bi-Metallic Bearing Materials-1

THE nature of bi-metallic bearings requires close control over every step in the manufacturing process. This is not only to insure uniform quality and precision of the finished product, but, what is equally important, to insure the quality of the *bond* between the metals.

* * * *

In many bearing applications, it is desirable to combine the properties of two or more metals or alloys in order to produce a material possessing qualities not obtainable in a single metal or alloy.

The most common of these materials in use today are:

1. Lead or Tin alloys (Babbitts) on a steel back.
2. Lead or Tin alloys (Babbitts) on a bronze back.
3. Bearing bronzes on a steel back.
4. Lead or Tin alloy overlays on a bronze intermediate layer and a steel back.

In the first three cases, the soft bearing surfaces are backed up with the strength of the steel or bronze backing. In the other, the bronze layer affords some protection to the shafting in case of a failure of the overlay bearing surface, while the steel provides strength.

In all cases, their value as a satisfactory bearing material is based entirely on the strength of the inter-metallic or metallurgical bond that can be obtained between the layers. The presence and quality of this bond is assured only by constant testing and checking throughout the manufacturing process, and bond testing has become the subject of major research by the bearing manufacturers.

The ideal bond test would be quick, non-destructive and positive, however these qualifications are not met by any test yet devised. X-ray and supersonic methods have been developed which are quick and non-destructive, but unfortunately, they have not proven to be positive. Large voids can be detected by these means, but very brittle bond, weak bond, or even a complete lack of bond with intimate physical contact, will pass these tests.

Thus, the only completely positive tests available so far are of a destructive nature. Figure I illustrates two destructive tests which are used and which are quite positive—however, the amount of machining necessary for specimen preparation makes them quite slow. The most widely used test is the so-called chisel test which is quick, positive, but destructive.

Off hand this appears to be a very crude method of testing but it has been proven that, with care, accurate interpretations of the results can be made and bond quality can be kept under close control.

Figure II illustrates the chisel test in operation. The chisel is well sharpened, grinding it at an angle of approximately 10-20 degrees, and then hammered down into the material till the bond area is reached. Holding the chisel at an angle of 20-30 degrees, it is driven along the bond line. Examination of the area after chiselling will indicate the quality of the bond, strength of the bond layer and nature of the bond.

Table I lists the general types of bonding encountered with lead and tin alloys on steel and bronze backs.

TABLE I

Material	*Type of Bond*
Lead Alloy/Steel	Ductile
Tin Alloy/Steel	Brittle
Lead Alloy/Bronze	Ductile
Tin Alloy/Bronze	Brittle

The ductility of the lead alloy bond on steel and bronze is due to the fact that the alloy layer formed during the bonding process is ductile. Tin, on the other hand, forms a very brittle compound when it is alloyed with iron or copper in the bonding process. These compounds are very hard and strong in tension, but are very weak in shear strength. Thus, when a chisel is run parallel to the bond line it exerts shear force and will tend to fracture the bond through the brittle alloy layer. The lining metal curls and fractures before the chisel in a pattern which is distinctive for each type bond. From an interpretation of the tests, a semi-quantitative evaluation of the results can be obtained.

The use and interpretation of the chisel method of testing will be more fully described in the second part of this subject.

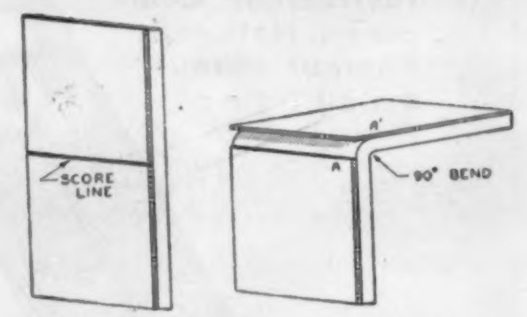
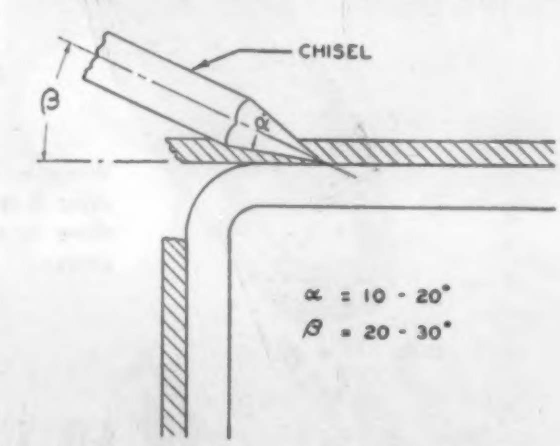


Figure II—Preparation of samples for Chisel Test



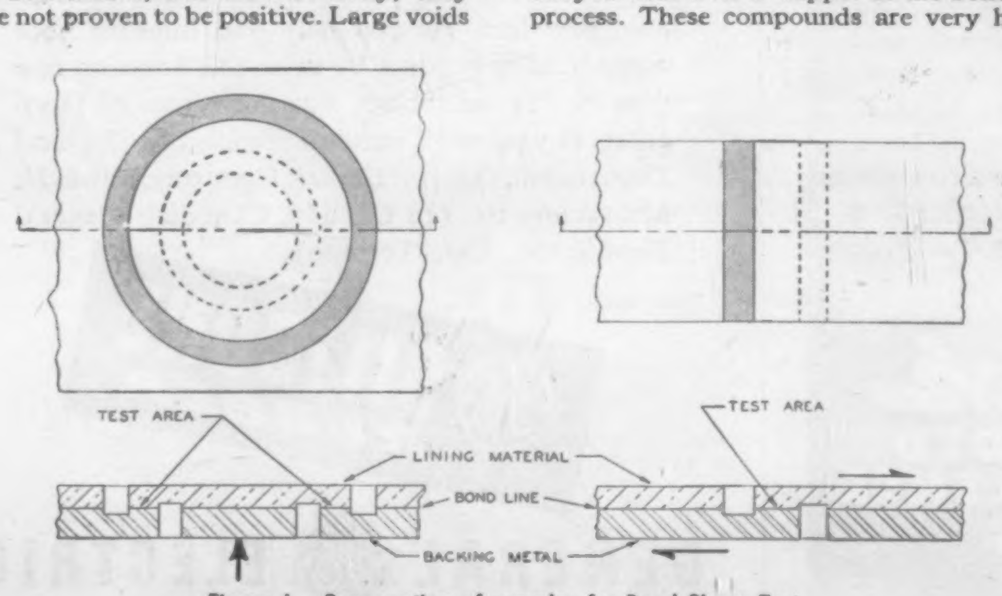


Figure I—Preparation of samples for Bond Shear Test

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Materials & Methods

THE MAGAZINE OF MATERIALS ENGINEERING

How Can Hardness Values Be Used in Metal Design?

Flexible, Corrosion Resistant Plastic Solves Gasket Problems

Engineering Properties of Iron Castings Improved by Heat Treatment

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How Copper-Base Casting Alloys Are Used in Electrical Industry

Industrial Applications of Thermosetting Laminated Plastic Tubing

Copper-Bearing, High-Strength Wrought Aluminum Alloys

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Materials & Methods Manual No. 65

December 1950

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